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ASSISTED BY A LARGE STAFF OF COLLABORATORS

FULLY ILLUSTRATED

Volume XIV

Protractor to Retina, Cyst of the

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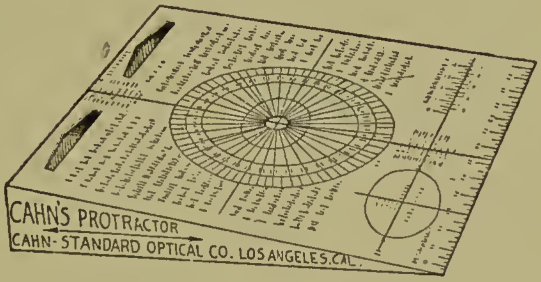
Protractor. A lens and prism centering device. This instrument is usually stamped with the different meridians on metal blanks of correct dimensions for cutting lenses to various sizes. In use, the protractor is placed on a cylinder lens which has been previously dotted, so that the meridian called for in the prescription will coincide with the dots indicated on the axis of the cylinder, and then cutting around the pattern with a hand diamond. See the illustration on p. 4963, Vol. VII, also p. 7212, Vol. X, of this *Encyclopedia.*

A. E. Ewing (*Annals of Ophthalm.*, p. 593, July, 1913) describes a protractor for use with the single cell trial frame, which consists of two circles made up of short, radiating lines of different lengths to represent the one, five and ten divisions of the circle. The proximal ends of the five and ten degree divisions rest on an imaginary circle which is the size of the outer edge of the 38 mm. ring of the trial lens, while the distal ends of the degree divisions rest on the inner edge of the mounting. For further accuracy in centering the mounting across vertical and horizontal lines, each 10 mm. long, is placed at the center of each of the circles. The circles are placed 21 mm. apart with their horizontal meridians in the same line, and at their upper margin a horizontal dotted line is drawn tangential to both circles. The circles are designated by "R" for right and "L" for left, the latter corresponding to the left eye and the former to the right eye, as the lenses are worn by the patients.


CAHN'S PROTRACTOR
CAHN-STANDARD OPTICAL CO. LOS ANGELES, CAL.

Cahn's Protractor.

To employ the diagram with the single-cell trial frame, it is only necessary to place the cylinder of the right eye over the right circle, with the edge of the trial lens of the left eye against the tangent of the left circle, and note the position of the usual short marginal guide line, which indicates the axis of the lens, in degrees on the circle. For the left eye the lens is placed over the left circle with the edge of the right lens against the tangent of the right circle, and the position of the left lens is similarly noted in degrees. This diagram is printed on the prescription blank for the glasses in order to have it always at hand and ready for use. It has proved to be a rapid, correct and satisfactory method for noting the axis of the cylinder when writing the record of the case, and for indicating it with a pen or pencil mark on a diagram for the use of the optician, as it plots the axis of the cylinder or the prism precisely as it is to be worn by the patient.

The conventional angular notation generally adopted in the graduation of circles, as used by Donders, and still in common use by probably the majority of ophthalmologists and opticians, has been retained. As only the 180 degrees are necessary for establishing the axis, the numbers are duplicated in the lower half of the circle in order to facilitate the reading.

A patented device (see cut) is Cahn's protractor, made of metal and set at an angle, so that the bottom is flush with the table and the top or back is raised so that a view of all the matter may be had without unnecessary stooping.

The center has an improved protractor for determining the axis of a lens. The lower edge has a millimeter scale, directly above which is the frame measure. There is a scale for decentration or prisms and another to determine the decentration of segments on bifocals. This feature is valuable for fused bifocal work.

At the top is a scale with two cut-outs, which enables one to find the amount of inclination of bridge forward and back at a glance. At each side of the protractor are given the standard sizes of rimless and bevel-edge lenses, both regular and short oval.

Protractor lentis. A peculiar intraocular muscle found especially in certain Amphibia, whose function it is to aid the accommodative efforts by pushing forward and withdrawing the lens.

Protrusio bulbi. See **Exophthalmus.**

Protrusio enorbitalis. (L.) Protrusion of the contents of the orbit as well as of the eyeball.

Protrusio exorbitalis. Protrusio oculi. (L.) Exophthalmus.

Protrusio oculi. (L.) Exophthalmus.

Protuberantia scleralis. (L.) A circumscribed backward protrusion of the sclera below the optic nerve entrance.

Proving. In homeopathy, a systematic testing and study of the pathogenic effects of a drug upon the human body supplemented when feasible by studying the tissue effects of larger, lethal, doses upon animals.

There should be a number of provers, male and female—ignorant of what drug they are proving and the dose—each provided with a note book and each examined periodically by specialists whose records go to form part of the proving. Each prover reports frequently to a director who, by critical quizzing, elucidates the symptoms. All these records are later collated by the director-general who puts the proving into shape for publication. A preliminary week is devoted to recording symptoms and to examinations. Each prover is then furnished with a preparation "A" (preferably a placebo) and directions how to take it. Other bottles, "A," "B," etc., are furnished from time to time as judged best. It is best to begin with the smallest dose, the highest attenuation, and increase till the prover is taking as large a dose as is safe. Symptoms should be noted for about three weeks after discontinuing, if they persist. Sometimes a proving is begun with a massive dose and its effects watched; if there be no subjective nor objective symptoms the dose is increased until it does produce some disturbance of health, which is then studied in its primary and secondary aspects. See **Homeopathy in ophthalmology.**—(J. L. M.)

Provoked conjunctivitis. ARTIFICIAL CONJUNCTIVITIS. INDUCED CONJUNCTIVITIS. FACTITIOUS CONJUNCTIVITIS. This condition is known by several other synonyms. See, *e. g.,* **Conjunctivitis artificialis**, p. 3094, Vol. IV; **Artefacta ophthalmia,** p. 609, Vol. I; under **Legal relations of ophthalmology** and various other sections of this *Encyclopedia.*

During the present war, for example, among the Moroccan troops of the French army, soldiers are frequently referred to the ophthalmologist with a diagnosis of "provoked" conjunctivitis. Aubineau (*Ophthal. Year-Book,* p. 410, 1916), however, states that in general it has not been possible to confirm the statement that these cases of conjunctivitis were "provoked." But in large measure they were due to inoculation of the conjunctiva by dirty fingers, or to exacerbation of old conditions, such as trachoma. One form of induced conjunctivitis has been rather frequent since the war, namely that due to the introduction into the eye of powered ipecac. This conjunctivitis is characterized by the absence of secretion, an eczematous appearance of the lid margin, a lardaceous appearance of the conjunctiva of the lower lid. Sometimes the remains of the powdered ipecac are found in the lid, and the localization of the lesions solely in the conjunctiva of this cul-de-sac.

A very good account of provoked conjunctivitis is given by van Schevensteen (*La Clinique Ophtal.,* Oct., 1916), translation in *Am. Jour. of Oph.,* p. 112, Apr., 1917).

Two types very sharply separated by their anatomical characters have been observed. These are:

1. The forms in which powdered ipecac was the provoking agent.

2. The forms in which the provoking agent could not be identified with certainty.

The powder of the root of ipecac contains as chemical elements some alkaloids, among which there is emetin. Its physiological effects, which interest us particularly, are an irritation of the naked skin and the mucous membranes; this action is particularly due to emetin which exerts a local irritating action on the mucous membranes and the integuments, especially when the latter present a certain acidity, and there it causes pseudovariola pustules.

When powdered ipecac is put into the conjunctival sac, there results within a few hours a considerable injection of the mucous membrane and a great swelling of the subconjunctival tissue (chemosis); a minimal secretion of mucus. These very violent, irritative and painful phenomena are usually accompanied by a swelling of the lids so considerable that the eyes cannot be opened. A single application suffices to produce these results. These symptoms are particularly acute in the lower fornix, and as this place is the easiest reached, contact of the chemical agent is there the most direct and its action the most marked.

A case of the highest irritation was noted in the upper fornix; the patient had simply turned the upper lid to make an application.

At the time of examining the fresh lesions the conjunctiva of the lower fornix is swollen, raised in great folds, although the surface is smooth, but at times it is covered by a pseudo-membrane; the color varying from scarlet-red to a livid or purplish-red.

After a few hours, especially if no further application has been made, the violent reaction recedes. The condition of the inferior fornix presents such a peculiar aspect that it is, so to speak, characteristic of this affection: the subconjunctival tissue is swollen, edematous, the folds of the conjunctiva are still deep, the vascular engorgements are covered by exudates; the color of the mucous membrane is especially noticeable, it assumes a yellowish-salmon color which persists for a long time.

The farther from the beginning of the "accident" the more the conjunctiva is smoothed out; its folds disappear, however, faster than the characteristic salmon color.

This whole evolution takes about three weeks. After that the eye returns to its normal state, if the application has not been repeated.

2. When the application is made repeatedly the violent reactions of the first application do not repeat themselves, a certain tolerance seems to be established; but although the painful symptoms disappear the anatomical changes become more and more characteristic. There is,

first, a very considerable thickening of the lower conjunctival fornix, the surface always remaining smooth, with the altogether peculiar salmon color, then a more and more marked disappearance of the vascular changes.

At an even more marked stage the thickened lower eyelids are slightly ectropionized, and on account of the turning out of the puncta lacrimalia, a slight tear stasis is produced, leading to a form which comes very near to a lachrymal conjunctivitis.

In the most obstinate cases the conjunctiva of the upper fornix presents certain changes. The vascular tracery of the tarsal conjunctiva disappear, blotted out by its thickening, and often at the upper edge of the tarsus fine, small points are formed reminding one very vaguely of primary trachomatous follicles. In a very extreme case we have seen the tarsal conjunctiva assume a uniform straw-yellow color.

The bulbar conjunctiva reacts in a certain way, also; it becomes pale, anemic, a little milky, as seen in certain cases of xerosis of the conjunctiva or in vernal conjunctivitis.

Sometimes a slight encroachment of the conjunctiva of the corneoscleral limbus on to the cornea is observed, especially on the inferior margin of the cornea; the bulbar conjunctiva appears much looser, less adherent to the subconjunctival tissue; it can be folded easily. We may, also, mention that the bulbar conjunctiva is easily injected; the usual manipulations, or a somewhat prolonged inspection, quickly produces a superficial perikeratic injection of the conjunctiva. It takes very long for this symptom to disappear. The instillation of a medicamentous and slightly caustic collyrium of zinc or copper sulphate in a weak dose instantly provokes a strong reaction accompanied by a flow of tears and a rapid curdling of these solutions, much more rapid in its appearance than in cases where no suspicion of this conjunctivitis exists.

In the cases in which the applications have been made very frequently the lesions persist a very long time after the applications have ceased.

The conjunctiva of the lower fornix remains thickened for a long time, the vascular network is slow in reappearing, it always appears covered over by the subconjunctival cellular proliferation, the salmon color, sometimes somewhat livid, shows white, slightly cicatricial striations, traces of cauterizations produced by the powder.

The secretion is very scant, as well in the beginning of the affection as even in the most chronic cases. In certain forms of superadded infection, that is, in which other chemical agents are employed after the primary application of ipecac, the secretion may become profuse to a certain degree. We have had occasion to observe an abundant and persistent secretion in a case in which the primary application of ipecac was followed by the touching with garlic juice. In this particular case, at first the discovery of garlic which the patient did not use in his food, a particularly severe reaction after instillations of nitrate of silver into the eye of the patient, and finally experiments *in vitro* in order to observe the precipitation of silver nitrate in the presence of garlic (allyl sulphur), had given us the key to the mystery.

In declining cases (without subsequent instillation of ipecac) the use of a collodion bandage untouched for three or four days has given us a very small amount of dry secretion, barely glueing the lids together and disappearing altogether when this bandage was repeated.

These ocular lesions may be complicated by lesions in the neighborhood. Sometimes, and especially in the beginning, the skin is simply macerated, sometimes ''erysipelatoid,'' like a beginning eczema; in other cases impetiginous pustules appear on the eyelids and all around the eye.

When a cure is effected the skin in the region around the eye retains for a long time a certain thickening and the impetiginous pustules disappear spontaneously, leaving slightly pigmented scars of a very light brown, a tint actually reminding one of the color of ipecac itself.

In the acute forms one must remember the clinical picture above described. Conjunctivitis, often unilateral, suddenly beginning, with very violent irritative phenomena; considerable swelling of the elevated and gorged conjunctiva of the lower fornix; scarcely any secretion, sometimes like a pseudo-membrane; impossibility of opening the eyes spontaneously; surroundings of the eye sometimes ''erysipelatoid.''

In the chronic forms the following symptoms occur: Frequently one-sidedness, lesion located in the lower fornix, salmon-color of the smooth conjunctiva, with deep folds, bare of vascular design, sometimes lesion in the upper fornix, scant secretion; the particular condition of the bulbar conjunctiva, very prone to become injected from ordinary manipulation or the installation of any collyrium.

These points: the improbable reasons alleged as the cause of the affection, its course and long duration, its resistance to all treatment, must not be neglected; finally the discovery of ipecac can only confirm the clinical diagnosis.

Procedures to find the ipecac by means of the microscope have been described. They are excellent and the positive results give still more absolute certainty; but they call for special instruments which are not always at hand, furthermore, they are not indispensable, the picture of a chemical conjunctivitis (especially from ipecac) is so typical, it differs to such an extent from a conjunctivitis due to a pathogenic microbic agent that with a little acquaintance the indicated elements of diagnosis suffice to identify this affection with certainty.

Certain individuals have used the powder for a year or more, in an intermittent fashion every two, three or four days; these applications are not very painful, especially after several repetitions; they keep the eye in such a condition that certain anatomical alterations persist.

Even in extreme cases the ocular lesions are limited to changes in the conjunctiva; in some cases only in which the dose was probably very strong we have observed a superficial keratitis which healed without detriment to sight.

The use of ipecac, therefore, seems to be without danger, for in spite of the reaction so violent at first we have not yet encountered a case in which after the cessation of the chemical agent a perfect cure has not resulted.

The treatment is very simple. Above everything else it is necessary to stop the ipecac.

Other forms differ from the ipecac type, especially on the part of the anatomic lesions. Their symptoms are (1) Predominantly bilateral, much more frequent than in the preceding type; (2) very chronic, torpid behavior, the affection lasting a long time and resisting all treatment; (3) superficial anatomic alterations of the inferior fornix of the conjunctiva, of a livid tint, the color of red of wine yeast, the vascular network remaining visible but slightly veiled; sometimes similar changes in the conjunctiva of the upper fornix; from time to time pseudo-follicles at the upper tarsal border; (4) in these cases the secretion is more abundant than in the ipecac type but is paradoxical, plentiful at the morning visit, and disappears towards the afternoon when a control visit, and especially an unexpected visit, is made; (5) the etiology given is always most strange, something so far-fetched and uncertain that it is impossible to admit it.

We have observed in some of these cases the use of soap, tobacco (juice or powder), pepper, dental powder; finally there are still other means equally queer and not always of the cleanest.

Provost, Addison John. An ophthalmologist and oto-laryngologist of Oshkosh, Wis. He was born in Theresa, Dodge county, Wis., Jan. 14, 1863, removed with his father's family to Menasha, and later to Rudolph, in Wood county. For a time he worked as conductor on a railway, whereby he earned the means for a medical education.

His medical degree was received at the Hahnemann Medical College, Chicago, 1891. For a time he practised at Monroe, Wis.. where, on Sept. 6, 1893, he married Miss Nell Sutherland. Of the union one child was born, a daughter. Shortly afterward the couple removed to Monticello, later still to Merrill, and, finally, to Oshkosh, where he practised as specialist in diseases of the eye, ear, nose and throat for many years. He enlisted in the medical (ophthalmic) department of the army, and, with the rank of captain, was stationed first at Ft. Riley, Kansas, later at Ft. Bliss. He died at Hot Springs, Ark., July 7, 1918.—(T. H. S.)

Prowazek bodies. A complete account of these occupants of trachoma nests is given on p. 834, Vol. I of this *Encyclopedia*. See, also, **Trachoma.**

Recently Stargardt (*Zeitschr. f. Augenhlk.*, p. 295, 34, 1916) has shown that the Prowazek corpuscles are found not only in trachoma but in inclusion conjunctivitis of the new-born, epitheliosis desquamativa, swimming-bath conjunctivitis, and in other affections of the conjunctiva. He thinks, however, that the apparently positive findings of Prowazek's corpuscles in acute conjunctivitis, spring catarrh, etc., were due to faulty technic. In his opinion the examination of epithelium, not of secretion, is necessary for obtaining reliable results. For that purpose he recommends the following method: Removal of fat from the slides by cleaning with 90 or 96 per cent. alcohol and holding them for a few seconds in the flame of a Bunsen burner. 2. Placing a drop of physiological salt solution of the size of 3 mm. on the slide. 3. Obtaining the material with the platinum scraper of Kuhnt. 4. Shaking off of the cells in the drop. 5. Spreading the drop with the scraper on the slide. 6. Drying in air. 7. Fixation in methyl alcohol for from 15 to 20 minutes. 9. Staining with freshly prepared Giemsa solution (1 drop in 1 ccm. of distilled water). 10. Irrigation by a strong stream of water. 11. Drying in air. The principle of these methods is to obtain a specimen of epithelial cells by keeping them as much as possible intact.

Proxinoscope. See **Zoetrope.**

Prussic acid, Ocular symptoms of poisoning by. HYDROCYANIC ACID. These are, during life, exophthalmia and diplopia. After death the eyes are fixed, prominent and wide open, and are possessed, furthermore, of a singularly life-like expression. See p. 70, Vol. I of this *Encyclopedia;* and **Legal relations of ophthalmology,** in middle third of article; also **Toxic amblyopia.**

Psammoma. SAND BODIES. A small, hard, fibrous tumor of the brain tissue, especially of the dura mater, optic nerve, pineal gland and choroid plexus, containing calcareous matter, or brain-sand. Sometimes called, after the discoverer, *Virchow's psammoma.*

A rare example of psammoma of the chiasm is described by P. Heinrichdorf (*Klin. Monatsbl. f. Augenhlk.*, Vol. 53, p. 185, 1916). de Schweinitz (*Trans. Am. Oph. Soc.*, 1914) points out that these new growths are not distinct tumors but indicate the presence of calcareous matter similar to brain-sand. These sand bodies are found in various tumors. Adami notes that psammomata are practically always of endothelial origin, and he explains their appearance as due to localized overgrowth of the capillary endothelium, at first in the main concentrically, so that the deposit becomes enlarged by the deposit of layer within layer of these endothelial cells. Thus, in the hemangio-endotheliomas of the dura mater microscopic examination will demonstrate, again, according to Adami, a collection of whorls of concentrically displaced cells, and sometimes a whorl may be found in the lumen of which red corpuscles are demonstrable. Whorls may also be noted which show hyalin changes, and frequently there is a deposition of calcareous salts in these degenerated areas. In other words, they become tumors which, when this calcareous change is marked, receive the name of psammoma.

The case described by Heinrichsdorf was that of a woman dead from general arteriosclerosis and granular atrophy of the kidneys. A greyish-red, nodular tumor of the size of a cherry was discovered at the anterior angle of, and below, the chiasm, but without connection with it. The left optic nerve was lifted in the form of an arch around the tumor by which it had been flattened. The tumor lay immediately before the infundibulum, from which it could be easily detached, although it extended into the sella turcica and possibly exerted pressure on the hypophysis. These relations to the adjacent parts are easily conceivable from the origin of the psammomas, *i. e.*, from the endothelia of the lymphatic spaces of the dura mater. A similar small tumor was discovered in this case on the dura mater of the inner surface of the frontal bone. The tumor showed all the characteristics of psammoma: collections and bands of short spindle cells; within these hyaloid cells and globules of lime. Clinically, there were no visual disturbances. If the tumor had grown one would have expected bitemporal hemianopsia and atrophy of the optic nerves, especially on the left. See, also, **Psammosarcoma**; as well as **Sand bodies.**

Psammosarcoma. A sarcoma containing a sandy deposit. De Schweinitz (*Trans. Amer. Oph. Soc.*, 1914) describes one of these tumors *in the orbit* of a girl, æt. 13, and gives an account of its successful removal with preservation of a functionating eye.

The patient, otherwise healthy, had noticed, about two and a half years before a tumor-like mass protruding from the upper and inner part of the left orbit; there was no history of trauma except a blow on the forehead previously noted. This growth did not appear in relation to any acute illness. It has never exhibited the slightest inflammation, nor has it ever been painful. Slowly the mass increased in size, pushing the eyeball downward and outward, but this disfigurement was unassociated with diplopia or loss of vision.

The orbital growth had compressed the frontal sinus but did not involve it and did not appear to proceed from it or from the ethmoid.

In the operation for removal a curved incision was made, beginning at the center of the left eyebrow and continued through the eyebrow and along the inner side of the nose to a point exactly opposite the inner commissure. The tissues were gradually dissected downward, the eyeball being properly protected with a horn spatula, and quickly there was exposed a plate of bone, which was continuous with the brow above and the inner edge of the orbit to the nasal side, sloping downward so that when exposed it presented a surface about 2½ cm. in height and 2 cm. in width. This bony capsule was apparently complete, and therefore with a fine grooved chisel it was opened along the orbital margin and the nasal side, and the plate of bone lifted very much as a flap would be raised. It was about 4 mm. in thickness, and as soon as the chisel penetrated the cyst-like cavity, a small quantity of perfectly clear fluid escaped, which unfortunately was lost, and within the bony capsule was found a mass of tissue which in consistence and somewhat in color suggested brain tissue. This was carefully removed with a scoop and preserved for examination. The bony capsule was then removed piece by piece, and was found to be complete, all of it, however, outside of the muscle cone. A slightly ragged edge which was left along the upper and inner orbital margin was cleanly removed with rongeur forceps, and the edges smoothed with a sharp chisel. A cavity now existed between the muscle cone and the inner side of the orbit of very considerable size, estimated to be large enough to contain a small egg. There was practically no hemorrhage, and it did not seem that any of the ocular muscles had been harmed in the operation except probably the tendon of the superior oblique. The only vessel which required ligation was the supraorbital artery. The wound was closed in the ordinary way with interrupted sutures, and a drainage tube inserted in its most dependent portion.

For a few days there was a rather liberal discharge of blood-stained serum, and at each dressing through the drainage tube the cavity was flushed with a saturated boric acid solution. On the fifth or sixth day the fluid which was regurgitated after the irrigations presented a few flakes of muco-pus. On the tenth day the patient went home, her house being in the neighborhood of the hospital. She returned, however, in twenty-four hours with some pain and swelling, which were found to be due to a small collection of pus within the cavity, which was evacuated, and after its evacuation healing was uncomplicated. The drainage-tube was removed, and no further complication of any kind occurred.

The eye returned almost entirely to its normal position. Vision was perfectly acute, and the only post-operative complication was diplopia, quite typical of paresis of the left superior oblique. This gradually subsided, and was noticeable only if the patient looked strongly down and to the right. When the diplopia was at its maximum the double images were fused by a 6-degree prism base out, and a 25-degree prism base down, that is, there was an esophoria of 6 degrees and a left hypertropia of 25 degrees. This became reduced to esophoria, 6°; left hyperphoria, 7°.

The removed mass consisted of numerous fragments of tissue, a portion of thin bone and periosteum. The tissue was soft in consistency, yellow in color, and contained minute points of hemorrhage. Microscopic examination demonstrated that the tissue was composed of a very cellular process in which were imbedded enormous numbers of refractile bodies; the nuclei of the cells for the most part were spindle in shape and presented decided irregularities in size. Here and there the cells were drawn out to form distinct fibrils which ramified between the tumor-cells. The tissue was well vascularized, the vessel walls in many instances being surrounded by the cells of the tumor, so that a single layer of endothelium separated the vessel from the tumor-cells. Here and there throughout the tissue free hemorrhage was noted. The refractile bodies were uniformly round; their centers pink, and the outer rims dark-blue in color. These bodies were found in all portions of the tumor-tissue. Unstained sections of the growth were treated with sulphuric acid. As no evolution of gas followed, the bodies were evidently not calcium carbonate in composition. They underwent solution and became represented by groups of crystals of calcium sulphate, hence they were composed mainly of calcic phosphate, or similar salts of lime, and as the cells were those seen in sarcoma, and as these sand bodies were so freely present, the diagnosis of psammosarcoma seemed justified. See, also, **Sand bodies**, as well as **Psammoma.**

Pseudagraphia. A form of the term *pseudo-agraphia.*

Pseudentoptoskope. A small microscope described by Laqueur (Graefe's *Archiv f. Ophthalm.*, p. 1, vol. 62, 1890) as consisting of three 20 D. convex lenses, intended for the examination of microscopic preparations.

Pseudo-achromasia. Complete (or monochromatic) color-blindness.

Pseudo-agraphia. A condition in which the patient can copy writing, but cannot write except in a meaningless and illegible manner.

Pseudoblepsis. PSEUDOBLEPSIA. A condition in which objects appear different from what they really are.

Pseudo-bulbar diseases. See **Bulbar and pseudo-bulbar diseases.**

Pseudo-bulbar paralysis. For the ocular signs, see p. 1324, Vol. II, as well as under **Neurology of the eye**, in this *Encyclopedia.*

Pseudo-calabar bean. See **Cali**, p. 1359, Vol. II of this *Encyclopedia.*

Pseudo-cataracta. (F.) False cataract.

Pseudo-choked disc. See **Neuritis, Spurious.**

Pseudo-chromæsthesia. (1) An anomaly in the perception of visual sensations, in which the vowels in words appear colored, each having a separate tint. (2) A condition in which sounds induce a sensation as of color; color-hearing; color-audition.

Pseudo-chromia. False perception of color.

Pseudo-coloboma. The mildest form of fissure of the iris, or merely an intimation of it, consisting in a form of partial, unilateral heterochromia of the iris. It is the last remains of the embryonic ocular fissure, which is tending toward closure.

Pseudo-conjunctivitis. A form of the disease that resembles but that is not a true conjunctivitis.

Fromaget and Bertemes (*Annales d'Oculistique,* Aug. 1916; review by Coulter in the *Br. Journ. of Oph.,* Feb., 1917) describe a form of unilated pseudo-conjunctivitis depending on homolateral frontal sinusitis. They give histories of three cases which they had observed in soldiers sent for examination, owing to suspicious conjunctivitis, and of one case which occurred in civil practice.

The disease is characterized by vivid redness of the entire palpebral and bulbar conjunctiva, which at first sight resembles that of acute conjunctivitis, but on examination with a loupe, is seen to be due to the presence of vessels. This is accompanied by slight lachrymation, but there is very little secretion and no gummy lids or redness or excoriation of the skin. There is no pain and no sign of disease in any other part of the eye or orbit. The attacks come on suddenly at intervals and, after lasting for periods which vary from 7 to 15 days, disappear spontaneously in from 24 to 48 hours. They are uninfluenced by the usual treatments.

These conditions were found to be associated with slight chronic frontal sinusitis, characterized by tenderness of the affected side on deep pressure on the angle where the inner and superior walls of orbit join, and by slight oozing of pus inside the external lip of the middle meatus. This latter may not be present at the first examination and may only become apparent after the fronto-nasal canal becomes freed spontaneously or by treatment. The authors consider that these cases are very similar in etiology to the cases of iritis or false iritis which accompany maxillary sinusitis, and are due to infection, probably through the venous anastomoses, and not to reflex action. For treatment they recommend inhalation of menthol with occasional applications of cocain and adrenalin. As the frontal disease is of a very mild type, operation is not usually necessary.

Pseudo-diascope. An appliance for producing an optical illusion depending upon a transposition of ocular impressions.

Pseudo-diphtheria bacilli. See p. 3998, Vol. VI, as well p. 3113, Vol. IV and p. 781, Vol. II of this *Encyclopedia.*

Pseudo-ephedrin. A mydriatic alkaloid, $C_{10}H_{15}NO$, in fragrant needles from certain species of Ephedra. See **Ephedrine (Pseudo-)**, p. 4477, Vol. VI of this *Encyclopedia.*

Pseudo-esophoria. A term applied by Savage to an oculo-muscular condition in which the far test shows orthophoria and the near test exophoria. See **Muscles, Ocular.**

Pseudo-exophoria. An outward tendency of the visual axis excited by diminishing the activity of the accommodative centers.

Pseudo-geusesthesia. A condition in which sensations of taste are accompanied by sensations as of color.

Pseudo-glioma. Plastic cyclitis. An exudate in the vitreous simulating glioma of the retina. See p. 5585, Vol. VI, and p. 3622, Vol. V, of this *Encyclopedia*

In addition to what is stated there it may be added that recently Sydney Stephenson (*Ophthalmsocope,* p. 14, Jan., 1916) and many others have discussed the diagnosis and pathology of pseudo-glioma, and from these studies one may conclude that the name is applied to a number of quite different pathologic entities.

Stephenson points out that the conditions most commonly mistaken for glioma include metastatic irido-cyclitis and extension retinitis. Gross tubercle of the choroid, too, as shown by W. A. Brailey (*Trans. Ophthal. Society U. K.*, p. 129, Vol. III, 1883), may also lead to confusion, although such cases are rare. Certain congenital anomalies, to which special attention has been directed by E. Treacher Collins (*Researches into the Anatomy and Pathology of the Eye*, 1896), may be difficult or impossible to diagnose from glioma. To this Stephenson adds the retinitis exudativa or retinitis hemorrhagica externa, of George Coats (*Royal London Ophthalmic Hospital Reports,* Nov., 1908).

Mayou and Collins have also shown that when a cyclitic membrane forms (behind the lens) it gives rise to a yellowish reflex, a condition that may clinically resemble glioma of the retina. In pseudo-glioma the retina becomes matted up with the exudate and ciliary body to form a large mass in which pigment cells proliferate and migrate. The choroid, ciliary body, and the ciliary processes are pulled inward, opening up the supra-choroidal lymph spaces and the root of the iris backward into the circumlental spaces, deepening the periphery of the anterior chamber. The epithelium covering the inner surface of the ciliary body often extends into the cyclitic membrane in the form of pigmented and partially tubular processes.

Swanzy remarks that "purulent choroiditis does not reach the latter stage in every case, but may remain confined chiefly to the choroid, vitreous humor and iris. The pain in these cases is not severe, and the affection occurring in children may be mistaken for glioma of the retina, indeed, the name of pseudo-glioma has been given to it. It must be stated that very recent investigations go to show that pseudo-glioma has its origin in the retina rather than in the choroid. It is distinguished from glioma of the retina by the muddy vitreous usually present with it, by the posterior synechiæ and by the retraction of the pupillary part."

Treacher Collins found in seven cases out of twenty-four eyes enucleated for glioma that the diagnosis was incorrect; Vetsch and Isler 4 times in 41 cases; Haab 5 times in 20 cases, and Greef 4 times in 21 cases. In nearly every case reported by Greef there was a retinal detachment caused by a lemon-yellow fluid in which there were many cholesterin crystals or fat cells with pigment crystals. He believes that the cause of the detachment was a choroiditis following infectious diseases.

The case of a girl 9 years of age who had for 3 weeks shown a yellow reflex from the right eye, is reported by Eversheim (*Archiv für Ophthalm.,* 70, I, 1909). This eye had converged for 1½ years. Behind the lens there were two yellowish-green protuberances which trembled slightly with the eye movements. Tortuous vessels could be seen on one and the entire retina was detached. Well anterior there was a second spherical bluish fold. The fine vascular twigs showed arborescent branchings with numerous small convolutions; throughout the retina there were many small hemorrhages. The second case was that of a boy just under three years of age. Behind the lens there were projecting folds of retina with coursing vessels. The retina was totally detached. On both sides it overlay the ora serrata, the pars ciliaris, zonule and posterior surface of the lens. In the middle of these the two leaves met and bulged backwards, lying close together, but still forming a flat fold which reached the papilla.

The microscopic findings lead the writer to the following conclusions: The disease begins either primarily or metastatically at some place or another in the retina, perhaps in one of the central vessels. Connected with this there is either a high grade nutritional disturbance or hemorrhages, so that a degeneration of the retina results, which at first involves the sensory nervous elements. The hemorrhage takes place both in the substance of the retina and between the retina and the choroid. When a cellular infiltrate is present in the latter it can be traced to the excitation produced by such hemorrhages. Through organization of this infiltrate and also from the sheath of the vessels, new-formed fibrous tissue may become attached to the choroid and form adhesions. Where detachment of the retina takes place the space is filled with hemorrhages and exudate from the diseased vessels. This may be so extensive that the lens becomes pushed forward and closes the angle of the anterior chamber producing increased tension. This condition of the tension, first normal then plus, is also found in true glioma and makes the diagnosis more difficult. The visible convoluted vessels are very striking and this and the cauliflower-like appearance of the base. and the fact that also in all three cases there was ectropion uveæ may be of value in the diagnosis of pseudo-glioma.

The above findings indicate, according to the author, that pseudoglioma, in a majority of cases, is a disease of the retina and not of the choroid.

Posey reports the case of a baby which was born with pseudoglioma in one eye, and in the other a coloboma of the iris with ophthalmoscopic signs of old choroiditis and secondary atrophy of the optic nerve. At birth the eyes were free from inflammation. The conditions were attributed to inflammation of the mesoblastic tissues resulting from syphilis in the mother.

Pseudo-heterophoria. See **Muscles, Ocular.**

Pseudo-hyaloid artery. These are threads of connective tissue attached to the papilla, the result of inflammatory action, or hemorrhage into the hyaloid canal; also the hyaloid passageway may be filled with the products of inflammation that subsequently become more or less organized—all of which may closely resemble a persistent hyaloid vessel.

Pseudo-hyoscyamin. See **Duboisin,** p. 4087, Vol. VI of this *Encyclopedia.*

Pseudo-hypopyon. A name given to the broken-down gummatous discharge into the anterior chamber often accompanying a syphilitic iritis. A good account of this sign in all its bearings is given by Rollet (*Révue gén. d'ophtalm.,* Oct., 1904; and in the *Bull. de la Soc. franç. d'Ophtalm.,* p. 261, 1908).

Pseudo-isochromatic. Seemingly of the same color throughout; applied to solutions for testing color-blindness, containing two pigments which will be distinguished by the normal eye, but not by the color-blind.

Pseudo-isochromatic plates. For a description of the best known exexample of these—Stilling's—see p. 2485, Vol. IV of this *Encyclopedia.*

While recognizing the great diagnostic use of Stilling's plates Helmbold (*Ophthalmic Year-Book,* p. 263, 1916) does not believe they should be used as the exclusive method of examination, as it is not possible to determine color defects with certainty, there being a number of cases now on record in which Stilling's plates were read without hesitation by dichromics or anomalous trichromics. Furthermore, there are persons who can decipher certain of the Stilling plates only with the greatest difficulty and are nevertheless color-sound.

Ishiwara has published two new pseudo-isochromatic plates designed to bring out red and green blindness. Each plate consists of a large number of round spots of various sizes, some being various tints of the test color and others of confusion colors. The test color spots are arranged in a figure, which the person tested can be required to outline. The color-blind will naturally include in his drawing both test and confusion colors.

Pseudo-isochromatic powders of Mauthner. One of the many devices employed in the detection of color-blindness. See Vol. IV, p. 2457 of this *Encyclopedia.*

Pseudo-leukemia. This disease resembles true lymphatic leukemia somewhat (see p. 7440, Vol. X of this *Encyclopedia*), and the symptoms from the ocular standpoint are of interest. Lymphoma of the orbit and of the lid are noticed in it but the tumor masses are not seen in the depths of the orbit as observed in the true form. See, also, the article by Stock (*Klin. Monatsbl. f. Augenh.,* April, 1906) and p. 1034, Vol. II of this *Encyclopedia.*

Pseudo-leukemia lymphatica. See **Blepharochalasis,** p. 1034, Vol. II of this *Encyclopedia.*

Pseudo-membranous cataract. A condition in which there are white spots on the lens due to iritis.

Pseudo-neoreopithelioma. See **Pseudoglioma.**

Pseudo-neuritis hyperplastica. PSEUDO-PAPILLEDEMA. PSEUDO-NEURITIS PROMINENS. OPTIC PSEUDO-NEURITIS. See **Neuritis, Spurious,** p. 8328, Vol. XI. of this *Encyclopedia.*

In addition to the matter there found it may be well to mention that Wood (*Ophthalmic Year-Book,* p. 244, 1913) has studied the condition of pseudo-neuritis and finds that the cases may be divided into two groups: pseudo-neuritis and pseudo-papilledema. The first group is much more common than the second. The most frequently met with form of the first group is the striate variety with slight blurring of the edges of the disk frequently seen in hyperopia. In the second form of the first group the disk presents a grayish-red appearance, woolliness of the edges, tortuosity of the vessels and some connective tissue adjacent to their origin. The appearance suggests that some portion of the "embryonic scaffold" tissue escaped obliteration during development. The pseudo-papilledema occurs either as a prominence of the nasal half of the papilla or a condition precisely simulating true papilledema. From microscopic studies made by Axenfeld and by Ormond it would seem probable that these cases are really enlargements of the optic nerve head due to primary edema which has persisted for years. Talmey examined the eyes of a man who complained of blurred vision six weeks after a severe cranial injury by blunt force. The ophthalmoscope showed what was deemed to be a bilateral pseudo-neuritis with unilateral medulated nerve fibers. The fields of vision are not recorded, but it is stated that "the function of the eyes was normal." Twelve weeks later the condition was unchanged.

A case that somewhat resembles Beard's classic instance is reported by Phinizy Calhoun (*Ophthal. Rec.,* May, 1915). It occurred in a woman, aged 43. The margins of the disc were blurred and obliterated by a slight swelling. The vessels were normal in size and position except that the temporal veins of the right eye were slightly full, and as the vessels approached the disc they were lost or covered in the slight swelling and striations of retinal tissue.

Pseudo-nystagmus. This symptom (sometimes found in normal eyes) is characterized by jerky movements which are more marked at the end of the globar excursions. It is found usually in hereditary ataxia, and in many other diseases of the nervous system. Uhthoff also noticed that it occurs in 46 per cent. of cases of multiple neurosis.

Pseudo-ophthalmoplegia, Wernicke's. See **Neurology of the eye.**

Pseudo-optogram. An optogram in which the rods strip off from the illuminated area and only the cones remain.

Pseudo-papilledema. See **Neuritis, Spurious**; as well as **Pseudo-neuritis hyperplastica.**

Pseudo-papillitis. See **Neuritis, Spurious**; also **Pseudo-neuritis hyperplastica.**

Pseudophakia fibrosa. A name applied by Czermak (*Bericht der Ophthal. Gesellsch.* 32, p. 335, 1905) to a shrivelled lens associated with a persistent pupillary membrane in a case of microphthalmia.

Pseudo-photesthesia. The perception of light on receipt of an abnormal stimulus, such as irritation of the Schneiderian membrane.

Pseudo-physostigmin. See **Cali**, p. 1359, Vol. II of this *Encyclopedia.*

Pseudopsia. False or depraved vision; pseudo-blepsia;

Pseudo-pterygium. A form of pterygium encroaching upon the conjunctiva from any direction, following injuries of the margin of the cornea.

The differential diagnosis between true and false pterygium is not difficult. Pseudo-pterygium is a fold of conjunctiva which has become adherent to the cornea at a point of previous ulceration or abrasion. The limbus is crossed by a bridge of conjunctiva beneath which a fine sound can always be passed. There is no canal beneath the neck of a true pterygium, and the passage of a sound at this point is impossible.

Steiner (*Klin. Monatsbl. f. Augenheilk.*, April, 1911), describes an operation suitable for such cases of pseudo-pterygium as occur in advanced trachoma in which the conjunctiva is dragged over onto the cornea. The membrane is dissected carefully off from the cornea and the separation from the sclera is carried down to the fornix. In the depth of the fornix, behind the membrane, a frontal incision is made which deepens the cul-de-sac to the orbital margin. The dissected conjunctiva is then turned so that it forms a continuation of the palpebral conjunctiva. The free margin which was upon the cornea occupies the bottom of the cul-de-sac. It is fastened here by sutures brought through onto the skin at the orbital margin. When the pseudo-pterygium occupies the fissural area it is split horizontally and one-half transplanted above the other half below. See, also, **Pterygium.**

Pseudo-ptosis. A condition simulating true ptosis. Drooping of the lid occasioned by swelling from edema, tumors and elephantiasis should not be classed with cases of genuine ptosis. So, too, the slight drooping of the lid so frequently seen in trachoma is due more to the additional weight of the lid, combined probably with paresis of the muscle of Müller.

The condition known as ptosis adiposa is the result of a relaxed skin which hangs down like a fold over the free border of the lid, and becomes more noticeable when the lid is drawn upward. This is due to the lack of rigidity of the fascial fibers of the levator tendon, that pass forward between the bundles of the orbicularis muscle to be attached to the skin of the eyelid.

Pseudo-ptosis, Hysteric. See p. 6124, Vol. VIII of this *Encyclopedia.*

Pseudo-pupil. The false pupil of invertebrate eyes. See **Comparative ophthalmology,** also **Pupil.**

Pseudo-refixation. A term used by Clifford Walker to indicate the performance by the observing patient under examination by the hemianoptic prism reaction of the act of refixation even when there is no light in the blind field.

Pseudo-sclerosis, Ocular relations of. Westphal-Strumpell's disease. K. Krabbe (*Centralbl. f. prakt.* Aug., 40, p. 146, 1915) describes an example of this disease as occurring with a slow, rhythmic action tremor, bradylalia and alimentary glycosuria. Otherwise there was a normal neurological condition, but typical pigmentation of the cornea in a zone 1 mm. wide along the limbus of both eyes. There were also total paralysis of fixation to the right, incomplete to the left, left enophthalmus, and abolished convergence.

Pseudoscope. An optical instrument through which, by means of an arrangement of prisms, objects are seen with their relief inverted. What is convex appears concave, and a figure in intaglio appears to be cut in relief. It was discovered by Wheatstone when experimenting with the stereoscope.

Pseudo-trachoma. A disease of the eye and limbus resembling trachoma. See **Conjunctivitis, Follicular,** p. 3103, Vol. IV of this *Encyclopedia.*

Pseudotropin. An isomeric form of atropin.

Pseudo-tuberculosis of the eye. See **Ophthalmia nodosa,** p. 8514, Vol. XI of this *Encyclopedia.*

Pseudo-tumor of the eye. See **Pseudo-glioma,** to which the term is usually applied. It is, however, also used to indicate any deposit simulating a true neoplasm. For example, Ginsberg and Paul Cohn (Graefe's *Archiv f. Ophthalm.,* 81 pt. 1917; abstract in *Oph. Review,* May, 1912) report a *pseudo-tumor of the iris* in a healthy boy, four years of age. After an operation on the globe a yellowish streak was noticeable in the right eye, which was smaller than the left, convergent, blind, not sensitive to the touch and exhibited minus tension.

There was a leucoma adherens, the rest of the cornea was clear, the anterior chamber shallow, and contained crystals of cholesterin, seen on focal illumination.

The iris was atrophic, and there was a small artificial coloboma with its base outwards. In the angle of the chamber reaching from the mid-point of the base of the coloboma to about 5 o'clock was a yellowish-red new-growth, with a finely nodular surface, and numerous vessels developed on its surface.

There was no evidence of any recent inflammatory disturbance, and the globe transilluminated except below.

In view of the fact that the tumor was rapidly increasing in size, and that the eye was blind, it was deemed advisable to enucleate it.

Pathologically the retina was found to be totally detached, signs of a long-standing irido-cyclo-choroiditis were present while the tumor was a cyst in the anterior layer of the iris tissue, i. e., in front of the pigment epithelial layer, which was found to contain large numbers of long, needle-shaped crystals, which were found to give the reactions of a fatty acid. There was no lens in the eye.

Psilosis. Falling out of the hair.

Psoriasis. The lid skin, and the dermal covering in the neighborhood of the orbit generally, may be involved in this disease, leading to falling out of the eyelashes, ectropion, trichiasis, symblepharon, xerosis of the conjunctiva and, occasionally, corneal ulcer. More frequently a simple conjunctivitis results, which disappears after the disappearance of the psoriasis. The treatment is that of the skin disease and consists chiefly in the careful employment of chrysarobin. See p. 2208, Vol. III of this *Encyclopedia.*

Psoriasis ophthalmica. (L.) Squamous eczema of the eyelids; scaly blepharitis.

Psorophthalmia. Palpebral conjunctivitis combined with blepharitis ulcerosa. See **Lippitudo pruriginosa**, p. 7496, Vol. X, and p. 1022, Vol. II of this *Encyclopedia.*

Psychalia. A morbid state of mind in which voices seem to be heard and images to be seen.

Psychanopsia. Psychic blindness.

Psychic blindness. Soul-blindness. Mind-blindness. Object-blindness. Visual apraxia. Pragmatagnosia. In this condition, a patient is unable to recognize by sight objects that were at one time entirely familiar to him. Those visual memories which one recalls in the recognition of particular objects are no longer accessible. See p. 1175, Vol. II of this *Encyclopedia:* also **Neurology of the eye.**

In addition to this matter, the *Ophthalmic Year-Book*, p. 247, 1916, has abstracted the following: Functional amblyopia as a war neurosis occurred in a case watched by Eder. The periphery of the loop-hole through which the soldier was shooting was struck repeatedly by bullets until his eyes began to water. His vision began to fail and within a few hours, complete amblyopia had developed. Eder explains the amblyopia as the result of a mental conflict between the subconscious instinct of self-preservation and the soldier instinct, resulting in hysterical amblyopia. Lagrange was unable to determine whether a case that came under his care was a malingerer of exceptional energy or a mono-symptomatic hysterical blindness. The man in question was a soldier in whose vicinity a bomb had exploded. He became unconscious, although no physical signs of injury could be found and on recovery of consciousness, was entirely blind. None of the tests devised were able to elicit light perception, although his pupils reacted freely. Finally Lagrange proposed to cure him by operation, at the same time assuring the man that he would not be eligible to further military service. Perfect vision resulted from this procedure.

Hertz and Ormond, on the other hand, give the history of seven cases of concussion blindness wherein the vision was completely restored by tonics, rest, hypnosis and suggestion. They do not believe that punishment, either suggested or real, is of any value, and these sufferers are truly psychically blind.

Psychic reflex. Certain mental states, such as induced by great fear or anger, cause dilation of the pupils.

Psycho-analysis. A form of suggestive treatment capable of employment in the treatment of hysterical amblyopia. For example, the two patients whose cases are reported by Ames (*Ophthalmic Year-Book*, p. 413, 1914) were quickly relieved of hysterical blindness by psycho-analysis, after one had been blind for some weeks and the other for more than two months. In each case there was some feature in the patient's' mental life which made vision undesirable or suggested that blindness was a refuge from trouble. The psycho-analytic methods employed made this underlying fact clear to the patient, and in each instance the unrestricted desire to see was followed by restoration of vision.

Psychochrome. A subjective mental association between any bodily sensation and some particular color. The colored thought-form of a mental concept. See **Chromatic audition.**

Psychochromesthesia. The condition in which auditory stimuli produce sensations or associated sensations of color. The faculty of colored thinking. See **Chromatic audition.**

Psychochromesthete. One who possesses the faculty of colored-thinking.

Psychogram. A visual sensation associated with a mental idea as of a certain number which appears visualized when it is thought of. The visualized but uncolored form of a mental concept. See **Chromatic audition.**

Psychology of the eye. PSYCHOLOGY OF VISION. Psychology treats of the science of mind, that is, systematic knowledge and investigations of the genesis, powers, and functions of mind. *Visual psychology* includes the mental concepts, activities and mental associations of eyesight as well as of the apparatus by means of which vision is accomplished. See, also, **Conscious vision**, p. 3184, Vol. V of this *Encyclopedia.*

This large and important subject has been partially and incidentally discussed under various captions in this *Encyclopedia.* See, for example, **Psychic blindness**, p. 1175, Vol. II; **Conscious vision**, p. 3184, Vol. V; numerous rubrics under **Neurology of the eye**; **Color-sense and color-blindness**; the introduction to **Physiological optics**; **Memory, Visual**; **Hysteria**; as well as many of the **Blind and Blindness** captions, especially those in Vol. II, pp. 1135, 1202, 1119, etc. See, also, **Psychoses**; as well as **Pupil** rubrics; **Intracranial visual apparatus**; **Optic nerve** and **Anatomy of the eye.**

The mental state involved in normal sight as well as those relations of mind to the pathological conditions which we know as blindness, with or without apparent lesions of the visual apparatus, may well occupy considerable space at this point.

Visual imagery and verbal thought. As Clara H. Town (*Illinois Med. Jour.*, Oct., 1914) has pointed out much of our thought, if not all, is carried on by means of memory images of various modalities, that most of our consciousness apart from its sensory elements is made up of memory images, the result of some past sensory experience. We all speak of seeing with our mind's eye; we are then, in more technical language, experiencing visual images. We also hear with our mind's ear, smell with our mind's nose, taste with our mind's tongue, and feel with our mind's fingers, though these figures of speech are not so generally employed. In these several instances we are experiencing auditory, olfactory, gustatory and tactual memory images.

A large part of our thinking is carried on by means of words, by means of internal language as it is called, or more technically endophasia. Our analyses of these word-images show them to be made up of visual images, or memories of the appearance of words and letters, of auditory images, or memories of the sounds of words and letters, and of motor images or memories of the speaking or writing of words and letters. There is present besides a consciousness of the meaning of the word which seems to belong inseparably to the complex of verbal images which constitute the word experience.

The construction of the retina and its relations to visual concepts. A. J. Ballantyne (*Oph. Review*, p. 332, Nov., 1912) has given a most useful abstract and review of two papers by A. Thierfelder (*Beiträge zur Augenheilkunde,* Part 80, May, 1912) with which the student of visual psychology should be familiar. For this reason it is here quoted almost *verbatim*. In these two communications Thierfelder outlines his attempt to construct a theory of the mechanism of vision, from the point at which light falls upon the retina up to the perception, retention, and reproduction of images. Perhaps hypothesis would be a more fitting term than theory, for it must be confessed that his views are erected on the slenderest possible foundation of acknowledged fact. The first paper, so far as it has any such basis, seems to rest on certain facts regarding color-blindness and positive and negative after-images, while the view put forward in the second is purely hypothetical, and the facts which are supposed to support it could apparently be explained equally well by other means.

To the rods and cones he applies the term ''visual cells,'' and to the cells of the outer nuclear layer the name ''cells of regeneration.'' Each visual cell has in front of it a corresponding cell of regeneration, and they are connected by a canal. These parts are surrounded by a photochemically neutral fluid. The inner segment of each visual cell contains the visual substance, the molecules of which are sensitive to light. The molecules are of different sizes, and each is acted upon by light rays of a definite wave length. Hence he speaks of red molecules, green molecules, etc. Again, the walls of the visual cells receive the terminal fibrils of the visual nerves, and these are the true end-organ of vision. Each fibril, like each molecule of the visual substance, is tuned to only one kind of light stimulus, and thus the author makes each visual cell so far comparable to the cochlea, in that it performs the function of analyzing each stimulus into its components, and is capable of receiving stimuli from every part of the color scale. When light reaches the retina the molecules of the visual substance are set in motion. Only those are affected which correspond to the component rays of the incident light. They pass by osmosis through the wall of the visual cell, and in doing so set up impulses in the nerve fibrils which terminate there, the red molecules stimulating red fibrils, the yellow molecules the yellow fibrils, and so on. Thus synthesis of the color stimuli is once more brought about. The exhausted molecules, which are now outside of the cells, find their way forward and by osmosis enter the cells of regeneration, where, under the influence of light and in the presence of a catalytic substance contained in these cells, they are once more rendered sensitive, and pass back into the interior of the visual cells. The photochemical changes accompanying the act of illumination are of a sudden character, a sudden unloading of accumulated energy from the molecules of the visual substance, but the re-accumulation of fresh energy, or restoration of exhausted molecules, is a slower process. So long as unregenerated molecules are present in the cells they either cause persistence of their stimulus (positive after image), or they block out rays of the corresponding color from incident white light, and lead to the appearance of complementary, or negative, after-images.

To the question, ''What is white?'' the author replies that it is a purely subjective thing, the combined sensation produced by all the rays of the solar spectrum to which our eyes are sensitive. Conventionally, we call an object white when the rays from it stimulate all the elements of our visual apparatus. If all our eyes have the same capacity, then we all mean the same thing when we say ''White.'' But it is not necessarily so. If red perception is absent the individual will still call sunlight white, while it really consists, for him, of all the rays from orange to violet, which in combination will give a color mixture complementary to red. Again, if a normal eye suddenly lose the power of seeing red, white light will have a blue-green appearance. These considerations are used to explain the phenomena of color-blindness, and to show their intimate relation to complementary after-images. To explain the anomalous colored after-images which result from over illumination and under illumination, and the color sensations resulting from the rotation before the eyes of black and white sectors, we are asked to assume that the red molecules of the visual substance are large, and the violet molecules small, those of the intervening colors being of intermediate sizes, so that the different molecules have, as it were, varying inertias, and behave differently according to the intensity of illumination. In the light-adapted eye the cells of regeneration become filled with molecules awaiting regeneration. Any light falling upon the retina will be largely used up in the restoration of energy to the exhausted molecules, and very little of it will reach the visual cells.

In discussing the way in which light waves come to be represented finally by nerve impulses, the author makes the suggestive statement that we are not dealing here with actual transformations of light energy into chemical energy, and of this into nerve energy, but that the state of affairs is more nearly comparable to what happens in a telegraphic system comprising a number of relays. The stimulus arriving at a given point is not converted into a new form, but merely sets up a change in a self-contained energy-system or circuit. Thus, he describes three such energy-systems in the visual process, (1) the optico-physical, comprising the energy of the light rays which reach the retina; (2) the photo-chemical, or the energy changes which occur in the visual substance; and, (3) the physiologico-chemical, which has its seat in the nerve end-apparatus. Between these systems there is no actual transference of energy, but the first acts to the second, and the second to the third, like the spark that fires the train of powder. Some such assumption seems necessary to explain the fact that there is no fixed or invariable relation between the strength of the stimulus and the intensity of the resulting sensation.

In the second communication Thierfelder deals with the *formation of visual concepts.* He begins with the statement that not only is every psychical process associated with a parallel physiological one, but the reverse holds good, namely that every physiological event, for example in the visual nerve fibres, has its corresponding psychological event. Visual sensations normally take their origin in a change in the visual cells of the retina which sets up a centripetal change in the nerve fibres. The nerve change, however, may be set up at the central end, and may travel towards the periphery where it excites activity in the visual cells. This will lead to a psychical change which will not differ essentially from that caused by a stimulus which came originally from the periphery. In the formation of a visual picture there are two distinct factors, namely, the external impression, and the internal excitation. In all normal circumstances these two are usually combined, but under certain conditions they may act independently. For example, the visual impressions received by the infant, by one who acquires the faculty of vision at a late date, or by an adult staring before him in a state of absent-mindedness, must be supposed to be the result of the external stimulus alone: while dream pictures and visual hallucinations are purely derived from a central excitation. To the first of these the author applies the term "passive," and to the second the term "active" sensations. In bringing about an active sensation the stimulus from the centre must reach the visual cells of the retina, and there set up the changes corresponding to those in a passive sensation. The picture which results will be exactly the same as the corresponding passive picture, if the nerve and the sense apparatus are excited to the same degree. Such perfection of the picture, including color as well as form, is only observed in exceptionally vivid dreams of hallucinations. Usually "active" pictures are merely pale counterfeits of the original impressions. They have an "inward" quality, but appear more outside the observer the more distinct they are.

To explain how the stimulation of a large number of separate fibres leads to the production of a combined picture, the author thinks it necessary to assume a cross connection in the nerve between all the fibres which take part in the conveyance of the impulses concerned in the formation of a visual concept. With each repetition of the same image, the bond between the fibres of such a system becomes so confirmed, that if one part of the system is stimulated the whole is stimulated. For example, if one sees only half of a known object the picture is "actively" completed. After a time an active picture can be at any time called up by an internal stimulus, but obviously the passive sensation must first be received, and the system of associated fibres developed.

Ballantyne ends his careful analysis of Thierfelder's second essay by remarking that in his enthusiasm for his theory the author seems to imagine that he has explained all the phenomena of visual memory, the reproduction of visual impressions, and a good deal more. He remarks, for instance, that "with such an arrangement of the nervous apparatus as that here pictured, the apparently unlimited power of forming concepts need no longer astonish us," and in another place, that the formation of a mental picture as the result of the simultaneous excitation of a number of nerve fibres is no more wonderful than the occurrence of movement when a certain system of motor fibres is stimulated. It does not seem to the reader that his explanation carries us very far.

Learning to see. Studies in this most interesting phase of the psychology of vision have already been discussed in this *Encyclopedia*, and the reader is especially referred to p. 1135, Vol. II, and to p. 7028, Vol. IX. In addition to the material there provided reference may be made to the essay of Moreau's (*Annales d'Oculistique*, Feb., 1913) account of the post-operative history of a case of congenital cataract. At 8 years of age the boy's left eye was operated upon, the cataractous lens being removed with its capsule. The power of visual interpretation came with extreme slowness. It was some time before he showed any tendency to turn his head in the direction of objects upon which the light was thrown, and which he promptly recognized by his sense of touch. He first interpreted his perception of the light reflected from luminous objects by saying "it burns." At first he was entirely without visual appreciation of movement, which apparently impressed him merely as so many successive alternations of bright and dark areas. After the visual notion of movement had been acquired, some time elapsed before he could differentiate between vertical and horizontal movement. In three weeks the cataract was removed from the second eye. Six weeks after the first operation he distinguished red, blue and yellow. A key he estimated as black or white according to whether it was turned from or towards the light. He was particularly fascinated by any object which had an inside and an outside, and everything thus characterized he spoke of as "a box." A cap, a saucepan, or a cup, was a box.

Eleven weeks after the first operation, careful study of the binocular visual fields with colored test objects 8 cm. in diameter gave the following results: Red, to right or left 70 degrees, up 60 degrees, down 25 degrees; yellow and green, to right and left and up normal, down 30 degrees. The boy's mental evolution closely followed his visual education. After a period of two months he had reached a confused perception of space. He played ball on the floor with an orange, but at the moment of seizing this or other objects he closed his eyes, relying on touch rather than on sight.

Attempts to teach him to read were only partly successful. He learned the letters, and went so far as being able to spell syllables. But he failed to coordinate syllables into words or words into a representation of spoken languages. After being for fifteen months under the observation of Moreau and of a Catholic sister, who devoted a great part of her time to him, he returned to his home in the country. A year later he was visited by the physician, who found that he had forgotten his letters. Moreau concludes by reminding us that removal of cataracts from the eyes of a patient born blind does not at once enable him to see the external world. Education is of supreme importance.

Psychic development of vision. A woman of 22 years, whose history is recorded by Grey and Emerson (*Ophthalmic Year Book*, p. 265, 1913), underwent an operation for removal of what proved to be an endothelioma of the right parietal cortex. She had previously been remarkably deficient in visual imagination, being incapable even of calling to mind the appearance of persons and objects with which she had been intimately associated. After removal of the tumor she promptly developed very keen visualizing power, including the ability to form mental images of objects not seen, but described in print. She also began to have visual dreams, although formerly her dreams had been limited to images of the motor, auditory and tactile types.

Psychology of traumatic amblyopia. A contribution to this subject is found in a paper by J. H. Parsons (*Lancet*, April 3, 1915).

In "shell shock" many cases are free from any definite organic lesion in the eye or visual paths. The history of a typical case is briefly as follows:

A man after more or less prolonged fatigue, induced by marching and exposure in the trenches, is incapacitated by the explosion of a shell in his immediate vicinity. He may be merely knocked down or thrown into the air, or more or less seriously injured or wounded by concussion, shrapnel, bullets, or shell splinters. Consciousness is lost for a variable time, but often not so far as to prevent automatic movements, so that the man may walk in a dazed condition to a dressing station. The mental equilibrium at this stage is much disturbed, and all memory of this phase is usually lost. The most striking feature of the case is that the man is instantaneously struck blind. The blindness may be associated with deafness, loss of smell and loss of taste, but all these are less frequent than the blindness. On examination it is found that there are intense blepharospasm and lachrymation.

The lids are opened with great difficulty and examination of the eyes is almost impossible. The writer is not aware of any record of the condition of the pupils at this stage. In the course of a week or two the blepharospasm diminishes and it becomes possible to examine the fundi. Of course, there may be local injury to the eye, but in uncomplicated cases the eyes are found to be normal. The pupils react to light, though in some cases the reactions are sluggish, and sometimes one pupil differs from the other, being larger, or more sluggish in its reactions. The fundi appear to be absolutely normal. By this time probably some restoration of sight has occurred. Light is perceived and large objects may be distinguished. As improvement occurs the patient manages to grope about, usually with his hands outstretched before him, and it is noteworthy that he does not usually stumble up against objects in his path. As soon as it is possible to take the fields of vision it is found that they are markedly contracted, and that indeed to a degree which seems scarcely consistent with the avoidance of obstacles in walking.

Parsons notes that recovery of vision is slow, but eventually it seems always to be complete. In the latter stages he has had cases in which the right eye is more affected and recovers more slowly than the left. It may recover to the extent of having only a central scotoma, though this may reduce the visual acuity to 6/60 or less. By perseverance and encouragement the patient may be induced to read a few lines of the types, and in some instances the manipulation of weak plus and minus lenses has led to the full 6/6 being read.

There are several suspicious symptoms in many such cases. The eye to recover last is often the shooting eye. Some patients show an obvious disinclination to return to duty. Some candidly admit to being in a "blue funk." In all there has been a complete mental upset, sometimes accompanied by hysteric symptoms—outbursts of weeping, etc., in the early stages. These features render it only too easy to jump to the conclusion that there is often a large element of shamming in the case. It is because there is very grave danger of cruel injustice being done to men who have faced the music and come battered out of the ordeal that Parsons attempts an explanation of the underlying psychology.

In the first place it is necessary to segregate these cases from allied conditions due to organic lesions or to malingering. It is not always easy to eliminate organic lesions of the type which causes so-called retrobulbar neuritis. It is still less easy to eliminate malingering, but as this depends upon a knowledge of the psychology of the individual, it forms a prime object of the following discussion. Since there is no demonstrable organic lesion these cases may be regarded as examples of injuries or wounds of consciousness. This does not imply that there is no neural lesion to account for the psychologic disorder, but merely that it had hitherto escaped observation. Parsons adopts the view of parallelism between physiologic neural processes and psychologic events or changes in consciousness.

The writer says that as regards the type to which the group under consideration belongs, it may be admitted that the disorder of the conscious processes varies with the nature and severity of the injury, and with the organization of the individual's character. Of these the latter is by far the more complex.

He adds that in the case of a soldier under shell fire the man is usually bodily fatigued, whereby his control is impaired. He has "the fear of death before his eyes" and is in a state of acute excitement, whereby his normal judgment is impaired. These conditions conspire to give his innate instincts ungoverned play. On the other hand, positive self-feeling, aided by suggestion and imitation and the sentiments of patriotism, the honor of the regiment, his own honor and so on, enforce his volitional control. At last, however, the shock comes which strikes him unconscious. It is not to be supposed that he is thereby anesthetized to these emotional storms. It is rather to be conjectured that he is rendered "subconscious," and hence the more a victim of his lower instincts. This view is supported by the emotional behavior of the men in the early stages, and by the fact that many of their actions can be revived by hypnosis.

The unconsciousness in these cases is to be explained physiologically by an abrogation of the functions of the highest level cortical cells. Recovery shows that the cells are not irretrievably damaged, and it is most likely that the block occurs on the afferent paths at the synapses of these cortical cells. Consciousness returns, but there is blindness. So far as objective evidence goes, the lower visual paths are intact and function normally. The optic nerves carry their impulses, at any rate, as far as the pupil reactions are concerned. The condition resembles uremic amaurosis. Parsons has seen it also in children after post-basic meningitis. The block is somewhere above the so-called primary optic centers—external geniculate bodies, optic thalami and superior colliculi. It, too, is probably in the synapses of the cortical cells, in this case the synapses of the fibers of the optic radiations. Sometimes such a block occurs physiologically and it is probably to be explained in the same manner.

Though in the cases under special consideration there can be little doubt that the early loss of vision has a definite neural basis, it must, Parsons thinks, be conceded that in the later stages the neural basis is of that undefined nature which we associate with so-called (functional) conditions. In other words, it is neurotic, but it is not "shamming."

The treatment consists largely in attempting to stimulate volitional control of the various emotions by suggestion, active sympathy, etc. As regards therapeutic measures, it should be remembered that fright causes great exhaustion of the suprarenal glands. See, in this connection, **Psychotherapy.**

Psychoses, Ocular. Mental disorders showing themselves chiefly in hallucinations (and sometimes in delusions) of vision. See p. 5688, Vol. VIII, of this *Encyclopedia.* These conditions have already been discussed under various other rubrics, such as **Hysteria, Neurology of the eye, Psychology of the eye,** and elsewhere. See, also, **Delirium,** p. 3808, Vol. V; as well as the paragraphs on *post-operative delirium* and other psychic disturbances at the end of **Cataract, Senile.**

As shown by W. L. Benedict (*Annals of Ophthalmology,* April, 1914) an examination of the ocular condition of psychopathic individuals reveals a relationship between the psychosis and certain changes in the eye. A knowledge of such relationship serves as a valuable aid to both psychiatrist and the ophthalmologist in the diagnosis and prognosis of many brain lesions. Owing to the close relation of the eyes to the brain extensive pathologic changes in the brain are attended with changes in the optic nerve, retina and the visible circulation of the retina and nerve. Benedict gives the result of his examination of the fundus oculi in 100 unselected cases of psychoses and tabulates the results. These cases he divides into four groups: 1. Psychoses due to or accompanied by organic brain diseases. 2. Imbeciles and epileptics. 3. Dementia præcox. 4. Functional psychoses.

The first group consisted of thirty-five cases; fundus normal in 14. The second group consisted of five cases: fundus normal in four. The third group consisted of fifteen cases: fundus normal in eleven. The fourth group consisted of fifty-two cases: fundus normal in twenty-six.

In the first group eight were cases of general paralysis, in five of which the fundus was normal, while two showed a neuroretinitis, the remaining one showed evidence of old cyclitis. All these cases had a positive Wassermann reaction.

Tyson and Clark claimed to have found fundus changes in 100 per cent. of their cases of dementia præcox but Benedict is quite unable to confirm this. It is obvious that in this connection, where it is a question of slight congestion or pallor, the personal equation of the observer counts for a good deal.

Benedict sums up his results as follows:—

1. Well defined disorders from extensive morbid conditions may exist for some time without change in the ophthalmoscopic pictures of the eye grounds.

2. Cases of dementia præcox, either slowly developing or rapidly deteriorating, show no associated disc changes peculiar to this condition, but, on the other hand, show a higher percentage of normal fundi than either the organic or functional group of psychoses.

3. In functional psychoses there is no definite association between the mental disorder and the ophthalmoscopic picture of the eye grounds.

Park Lewis (*Annals of Ophthalmology*, April, 1914; review in *Oph. Review*, p. 24, Jan., 1915) describes especially the psychic (ocular) disturbances in certain hysterical cases. Case one was that of a little girl ten years of age who became suddenly quite blind after having her refraction corrected. She had a considerable amount of hypermetropia and one eye was amblyopic. When first wearing the glasses she complained she could not see distinctly with either eye and the father then exclaimed that she was going blind, which suggestion was promptly acted upon by the child. When seen by the author she declared she could not distinguish light from darkness, but there was no lesion in the eye and the pupillary reflexes were normal. Under simple suggestive treatment vision was restored in three weeks.

Case two was very similar, the patient being a girl of fifteen who in consequence of the recent loss of her father was suddenly called upon to assist largely in the maintenance of her family. In this case there was a history of extensive and frequent nasal hemorrhage without any discoverable cause. In the right eye there was a small, black, pigmented patch near the macula. This patient also rapidly recovered her vision on being reassured that her employer was interested in her welfare.

Case three was a girl of twenty who suffered from intense photophobia and blepharospasm, so that she was unable to bear the slightest natural or artificial light. Unfortunately she had met with injudicious treatment, being kept for months in a dark room. This condition had lasted for four years. With great difficulty the eyes were examined and with the exception of a small amount of astigmatism were found perfectly normal. General examination showed that she had a floating kidney. She was fitted with a support for this and with a pair of glasses to correct her astigmatism. She was then encouraged to use her eyes and not to protect them from the light. She soon made a perfect recovery.

Case four was that of a girl of sixteen who was living in a state of fear with an insane mother. She was attending the hospital for an angry, abraded ulcer on the skin in the corner of her left eye which did not improve under treatment. After the removal of her mother to the asylum and the girl being placed under proper care the ulcer immediately healed.

Case five is of great interest and reported at considerable length. It concerns a man, whose age is not stated, who had suffered from a slight injury to the left eye from a piece of cinder. The persistent pain after this led the physician in charge to make a diagnosis of glaucoma and as the pain was not at all relieved by the use of strong solutions of eserine the author was called in with the view of operating. Ever since the accident, which was then a year old, the patient had been unable to work and three months before the author saw him had suffered from right hemiplegia.

When examined the vision in both eyes was found normal and there was no change in the fundus. The visual color fields were inverted. A careful neurological examination was made and it was decided that the hemiparesis from which he was still suffering was of functional nature. On being reassured and advised that nothing was going wrong with his eyes he made a rapid recovery.

Case six was a patient who had suffered from a severe nervous breakdown with athenopia and intense agarophobia. He was found to be suffering from nasal obstruction due to enlarged middle turbinates. When these were removed his other symptoms rapidly improved.

As Park Lewis points out, if any of these cases had come under some of the various faith-healing systems they would have been immediately claimed as marvellous successes.

The author acknowledges his indebtedness to Pansier's monograph on the eye in hysteria for several of the facts recorded in his summing up of the conditions that are to be found in hysteric eye affections. Amongst these he gives first place to abnormalities of the visual color fields. Next come modifications of the sensibilities of the ocular region. A noteworthy point in this connection is that in spite of the apparent insensibility of the conjunctiva, excitation of this membrane will produce an abundant flow of tears. The secretion is produced rather more slowly, however, than in the normal eye.

Hysterogenic zones are of two kinds, those that produce a spasmodic action and those which produce a lethargic condition.

To detail all the symptoms produced by hysteria in the eye is unnecessary, but particular attention should be drawn to those cases, seen usually in unmarried women who are no longer young, and described by Donders as painful accommodation. With this condition we are all only too familiar. Perfectly healthy eyes in which the slightest attempt at work is followed by violent pain in the head, photophobia, burning of the lids, etc., in which no ophthalmic treatment is of any use.

Psychotherapy. MENTAL TREATMENT. SUGGESTION. HYPNOSIS. HYPNOTIC SUGGESTION. See **Hypnotism,** p. 6112, Vol. VIII of this *Encyclopedia.*

The word "psychotherapy" has recently come into widespread use in the United States, as a comprehensive term to include all endeavors to further mental and physical well-being by influencing the mental life. While the attention of American physicians and psychologists has been attracted to the subject, and these have devoted special efforts in recent years to advancing the scientific understanding of the psycho-physiological problems involved and to the improvement of psycho-therapeutic procedure, interest in what is usually called the influence of the mind over the body has expressed itself to a peculiar degree in America in various popular movements which have aimed at putting this influence into practical service. Its scope has thus been enlarged to denote a branch of therapeutics.

In seeking health by psychotherapy it is essential to teach people to live more wisely, more actively, and with a serener outlook, to strengthen the power of self-control, of concentration, of initiative, of sympathy. It has been recognized that nervous ailments, especially psychoneuroses, are very common, and are not necessarily confined to those who are considered sick. Disorders of the highest faculties of the personality, modifications of consciousness, weakness of judgment, impairment of self-control, obsessions and fixed ideas of all sorts, anxieties, fears, morbid impulses, and a perversion of the highest ethical and social feelings are varieties of psychoneuroses which are accompanied by physical symptoms, and have their causation primarily in the realm of the mind, and should be attacked from the mental side. The teachings of those chiefly identified with the progress of psychotherapy as a science and a true healing art in America bear especially upon the treatment of this group of nervous disorders, and often verge closely upon education and ethical instruction.

Preachers and educators, as well as physicians, have in such cases found help in psychotherapy. In the so-called Emmanuel movement an attempt was made to place cooperation between the physician and the clergyman on a systematic basis. It was begun by the Rev. Elwood Worcester in his church, Emmanuel (Protestant Episcopal), Boston, in November, 1906, as a "class for the treatment of nervous disorders," and had an advisory board of physicians. The work of this church had numerous imitators, within and outside of its own denomination, who adopted its methods in varying degrees and the movement soon provoked much controversy. A large literature resulted, in part centering about the leading publication of Dr. Worcester and his associates, *Religion and Medicine, The Moral Control of Nervous Disorders.* This book quickly ran into several large editions and was followed by other publications of this church. The Emmanuel form of psychotherapy was officially described as "moral and religious re-education." While it employed suggestion, in the waking state and in rare cases under hypnosis, it relied chiefly upon efforts to guide, strengthen and enlighten the patient by the influence of moral and religious teaching. A reaction as the result of the criticism that had been aroused came soon after the movement had attracted wide attention, modification tending toward greater conservatism having already been made by Emmanuel Church in January, 1908.

While the work of Dr. Worcester was based in its inspiration more immediately upon the teachings of Dr. Paul Dubois, of Berne, whose book, in its English translation, is called *The Psychic Treatment of Nervous Disorders,* it was unavoidable that its special origin should be associated with the activity of believers in Christian Science and in New Thought in spreading the doctrine of the power of the mind over bodily conditions, and in insisting upon the effectiveness of a hopeful, confident frame of mind in the maintenance of health. While unscientific, and therefore open to the charge of unsoundness, the forms of psychotherapy developed under the influence of these doctrines have had an exceedingly large vogue in America. It is probably also true that the prevalence of these and similar cults of the same general motives has been influential in stirring the medical profession to the new activity which it is manifesting in this direction.

The pioneer in America in the development of psychotherapy as a method of medical treatment based on sound psychology was S. Weir Mitchell, of Philadelphia. While he has himself used other terms, his famous "Rest cure" was in essentials a highly specialized form of psychotherapy. Besides rest in bed it included the psychotherapeutic features of, first "isolation," and second, mental and moral "re-education." The studies of Boris Sidis in suggestion and of Morton Prince, of Boston, in dual personality, throwing light upon the obscure question of mental "complexes" which figure as a basic phenomena in the obsessions and perversions of the mind; the studies of Professor Jastrow, of the University of Wisconsin, in the subconscious; of Professor Hugo Münsterberg, of Harvard, in experimental psychology; the work of Dr. Frederick Peterson, of New York, in developing the psychotherapeutic method of "psychoanalysis"; and practical applications by Dr. Richard C. Cabot and Dr. James J. Putnam are among the notable features in the recent development of scientific knowledge regarding psychotherapy, and in its more purely medical aspects in America.

Dr. Richard C. Cabot, who lays much stress upon the educational side of psychotherapy, upon what he has called the "work cure," and upon habit formation and character building, has pointed to the writings of William James as the best of guides in psychotherapeutic efforts, especially in those wider applications to ordinary life which this word has found in American usage. His phrase the "Religion of healthy-mindedness," of which he was himself a preacher, serves to convey the central idea underlying this development of psychotherapy. Josiah Royce has laid stress upon the part a philosophic idealism plays in the establishment of a mental attitude which is conducive to health, and finds in "Loyalty," to causes, a specific for the restoration of much mental disorganization with attendant physical benefit. *(Standard Encyclopedia.)*

The following disposition of this method of treating ophthalmic cases was made by the late D'Orsay Hecht and the Editor of a *System of Ophthalmic Therapeutics,* p. 629, in dealing with this caption:—

Although additional mention might be made of psycho-therapy in the treatment of neurasthenic, neurotic and hysterical forms of asthenopia, dysopia and amblyopia, it was felt that the successful psycotherapist is born, not made; if he does not unconsciously and naturally exercise that persuasive control over his patients that in all ages has been more or less definitely recognized as a valuable curative asset, no amount of printed verbiage will furnish it. Moreover, a long-continued, faithful and earnest study of diseased eyes, preceded by a sufficient consideration of the anatomy, physiology, pathology and therapy of the organism of which they form a small but far from negligible portion, is the best foundation for that mental treatment which most patients demand and many require. That knowledge may be acquired but the personality of the ophthalmologist is a factor in therapeutics which, although of prime importance, no book or books can do much to modify. Lacking infinite patience, a convincing air, an evident belief in his own powers of healing and a certain kindly sympathy with the patient's troubles the physician, well-equipped professionally, cannot apply his remedies to the best advantage and may not hope to avail himself of the powers inherent in applied hypnotism and suggestion.

Of course, proving oneself to be *suaviter in modo* is not the only passport to success in treating the increasing proportion of neurasthenic and neurotic eye patients that crowd our waiting-rooms, but to ignore its importance is to drive many sufferers into the ranks of the Osteopaths, Christian Scientists, Mental Healers, New Thought, *et hoc genus omne:* It behooves us, then, so far as in us lies, to temper our knowledge with what wisdom we possess or may acquire.

A very helpful article, discussing the foregoing, is that of F. B. Eaton *(Ophthalmology,* p. 98, Oct., 1913.)

Pterodactyl. A remarkable, extinct winged reptile, the remains of which are met with in the Jurassic and Cretaceous systems. There are numerous forms of pterodactyls which are included in the extinct order Ornithosauria. The head was relatively large and snout-like, the long jaws being furnished with simple and pointed teeth, implanted in separate sockets. The orbit and, consequently, the eyeball were very large, the sclerotic having the avian-reptilian ring of bony plates, and the nostrils approximated to the orbits.

Pterospermum suberifolium. A plant found in southern India. The flowers are used in migraine.

Pterygion. (Obs.) Varicose excrescence of the conjunctiva; also, the French form of pterygium.

Pterygium. From the time of the Ancients, surgeons have been interested in pterygium and its operative treatment, and it would seem almost remarkable that a structure so small, so uniform and so approachable, should have accumulated such an extensive literature, an amount, it might be said, disproportionate to the importance of the disease. A careful review of the literature will show, however, comparatively few names associated therewith by reason of additional knowledge of importance contributed to the subject.

Through centuries the name only has remained constant, the etiology, anatomy, pathology and therapy having undergone various changes and revisions until the present day, when we at least think we understand the true nature of the condition.

Of Greek derivation the name pterygium means "a little wing" and has reference to the very characteristic if not constant appearance of this conjunctival structure, triangular in shape, with its apex, or head, at the corneal limbus or on the cornea, and extending backward, fan-shaped, to become lost in the bulbar conjunctiva near the inner or outer canthus, as the case may be. The true pterygium always has its origin in a pinguecula, a theory first promulgated by Horner, (*Correspondbl. f. Schweitzer Aerzte,* 1875, p. 554) and later established by Fuchs (Graefe's *Archiv für Ophthalmologie,* XXXVII, 3 p. 143, 1891; and Ueber das Peterygium, ibid XXXVIII, 2, 1892, p. 1). According to Parsons (*The Pathology of the Eye,* 1, p. 107, 1904.) Zehender first derived pterygium from pinguecula, but gave no proofs.

It is therefore only to be found on the nasal or temporal aspect of the bulbar conjunctiva within the palpebral fissure. Similar structures placed vertically above or below, which have been occasionally noted and reported, are not true pterygia, but are cicatricial conditions more of the nature of symblepharon, and were better nominated pterygoid or pseudo-pterygia.

From the pinguecula progress is made forward, and an attachment formed at the corneal limbus, from which point further progress and invasion of the cornea slowly take place until the head of the pterygium may occupy the very center of the cornea, or even pass beyond this point. The conjunctiva is thus passively drawn in the direction of the advancing head, the thickened and folded conjunctiva known as the body of the pterygium, with its diverging margins resembling very much the tail of a comet. The slightly constricted portion differentiating the head from the body, and always at or over the limbus, is called the neck. In the presence of a formed pterygium the pinguecula has disappeared. Pterygium is therefore not a new growth, but an overgrowth and displacement, and rearrangement of pre-existing tissue.

Primarily, pterygium always attacks the nasal side of the eyeball; not infrequently one will develop on the temporal side later. Yarr (*Journal of Tropical Medicine,* 1, 6, 1899, p. 155) states that he has never seen a single temporal pterygium. He believes that when one exists in this situation, it is always consecutive to one on the nasal side of the same eye. Both eyes are generally affected, although not necessarily at the same time, and occasionally the same individual will have four pterygia.

According to Saemisch (*Handbuch der ges. Augenheilkunde,* V, 1, p. 417, New Ed.) pterygium is twice as frequent in males as in females; and with few exceptions an individual with a formed pterygium has reached his fortieth year.

That pterygium may be malignant in the sense of being progressively destructive, is evidenced by the fact alone that its tendency is to advance steadily toward the pupillary area of the cornea and in this way to destroy vision. Chisholm (*Medical and Surgical Reporter,* LVIII., 1888, p. 633) for example, reported three cases of pterygium which had completely covered the cornea, one of which extended almost to the opposite limbus. Similar cases have also been recorded by Ryerson (*Medical Record,* XXXIX, 1891, p. 536.)

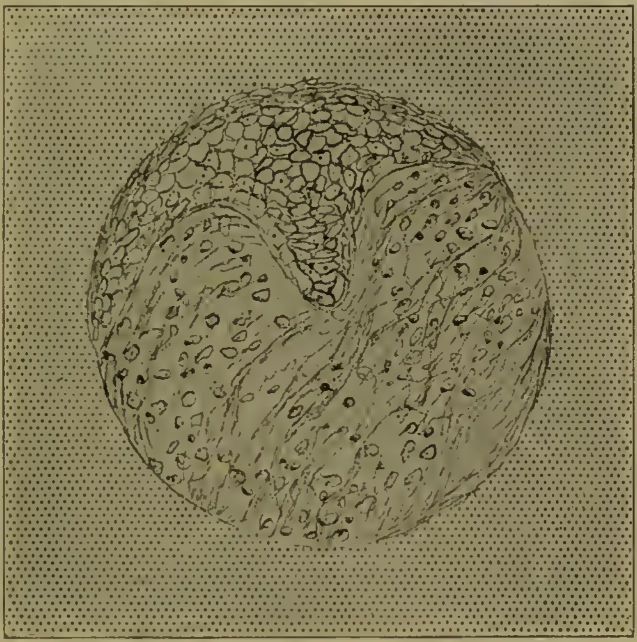
Cyst formation in a pterygium, cases of which have been reported by de Schweinitz (*Transactions of the College of Physicians,* Phila., XXXI, 1908, p. 319) and by Strachow (*Klin. Montasblätter f. Augenheilkunde,* May, 1908, p. 563), and epitheliomatous degeneration, are changes occasionally noted. X. da Costa, of Lisbon, maintains the possibility of epitheliomatous transformation of the head of the pterygium, and describes two cases in which histologic examination showed a distinct epitheliomatous structure. Three similar cases are cited from different observers.

Such changes not only complicate the operative procedures then necessary, but their possible occurrence is an additional argument in favor of the removal of any pterygium.

That recurrence will at times follow all forms of pterygium operation has been the experience of every surgeon, but it is well to bear in mind the observations on this point made by Czermak and Elschnig (*Die Augenärztliche Operationen,* 1907-1908.)

These authors state that the really active part of a pterygium is the limbus portion. If this portion be carefully removed and the wound covered with conjunctiva, there can be no true recurrence. The conjunctiva may form here a cicatricial pterygium which differs materially from a true pterygium, and especially in that it is not progressive.

The question of activity in a pterygium is a most important one, and one at times difficult to decide. Classed as progressive, and stationary, it becomes the surgeon's duty to determine first, which form is being dealt with. The importance of this lies not so much in the simple question as to whether or not to operate, for it is proper to operate upon any pterygium, for cosmic reasons, and for the relief of accompanying chronic conjunctivitis, undue astigmatism, etc., but if progressive, operation should be urged as imperative. In other words, the stationary pterygium *may* be operated upon, the progressive pterygium *must* be, and both *should* be.



Section of Pterygium. (Johnston.)

Clinically, the stationary pterygium is, as a rule, thin, pale, and poorly defined; it contains but few blood vessels, not exceeding much in size those of the normal conjunctiva, and has a flat head of irregular outline, lying on or passing into the cornea with little perceptible elevation, and scarcely invading the cornea beyond the limbus. At times the head is bordered by a narrow, glistening or tendinous-looking line. The whole is evenly covered by epithelium. Such a pterygium is stationary.

The progressive pterygium, on the other hand, is apt to be darker in color and more vascular, the vascularity seeming to be due to new-formed as well as to enlarged pre-existent vessels. It is thicker, and the head shows material elevation, and is often bordered by a grayish, gelatinous-looking material free from blood vessels. Any great amount of vascularity in the neck, and approaching the head, is very suggestive of progress.

In classifying a pterygium as stationary or progressive, then, a careful examination and critical analysis of the head and neck must be made, and the clinical signs of activity will be found to be the same here as elsewhere in the body.

Pseudo-pterygium. The differential diagnosis between true and false pterygium is not difficult. Pseudo-pterygium is a fold of conjunctiva which has become adherent to the cornea at a point of previous ulceration or abrasion. The limbus is crossed by a bridge of conjunctiva beneath which a fine sound can always be passed. There is no canal beneath the neck of a true pterygium, and the passage of a sound at this point is impossible.

THE DEVELOPMENT OF PRESENT-DAY METHODS OF PTERYGIUM OPERATION.

The first surgeons to operate for pterygium naturally practised simple excision or extirpation. This was followed by partial excision and various sections and resections.

Celsus (Rome, A. D. 1) advised separation of the pterygium by a scalpel after lifting it from the sclera by a thread passed beneath. Aetius sawed it from its attachments with a horsehair. Heister made a single incision through the pterygium, with the idea, presumably, of eradicating it by destroying its circulation.

Saint-Yves cut through "cross-wise" and pulled the flaps away. Acrel cut through the pterygium on the cornea, and according to Richter (*Treatise on Surgery*—Göttingen, 1771, p. 92) was the first surgeon to advocate and practise removal of the head. Scarpa (*Traité des maladies des yeux*, 1802-1816) in the early part of the nineteenth century removed the head from the cornea with forceps, dissected backward freely, and three or four millemeters from the limbus separated the pterygium by an incision concentric to the cornea. Scarification of the pterygium in a direction perpendicular to its long axis was recommended by Benjamin Bell in 1813. Cauterization and scarification, after separation, were also practised by Woolhouse and Beer, and caustics, such as silver, zinc, etc., were for a time used by others.

Coccius (*Lehrbuch der Augenheilk.*, 11, 267, 1854), was probably the first to introduce conjunctival sutures to cover the exposed sclera. He is thus credited by Arlt, although, according to Fuchs (*Text Book of Ophthalmology*, Am. Ed., 1908, p. 128), Arlt himself deserves the credit for having made the operation for pterygium a success by demonstrating the necessity of closing the conjunctival wound. Fox (*Diseases of the Eye*, 1904, p. 129), on the other hand, gives this honor to Fano.

In 1842 the method of ligation was introduced by Szokalski (*Rozer und Wunderlich Archiv*, 1845, No. 2.) Three ligatures were passed beneath the pterygium, one at the limbus, one near the base, and a double one in the middle. The inner and outer ligatures were tightly drawn and knotted, the middle one was used first to pull the pterygium from its scleral attachments, and was then tightened and the ends fastened to the cheek with collodion. After the death of the pterygium, which occurred in a few days, it was excised. This method in the opinion of the writer is, at the present day, both unnecessary and unsurgical, and while it is carefully described and illustrated in many text-books, no form of pterygium could warrant its selection.

About 1855, the elder Desmarres (*Traité theorique et pratique des maladies des yeux*, 2d edition, 11, 1855, p. 168), devised the method of transplantation for the purpose of diverting the growth from the cornea. Not only was this object accomplished, but it was found that after transplantation the pterygium atrophied. Desmarres' principle was one of great and lasting value, and he must ever receive a royalty on the credit given any transplantation operation for pterygium.

The actual cautery as a means of destroying the head and neck of a pterygium has been strongly advocated by Coe (*Annals of Ophthalmology and Otology*, V, 1896, p. 250), and F. B. Loring (*Medical News*, LXXXI, 211, 1902.) Both Coe and Loring applied a heated platinum wire to the corneal and limbus portion of the pterygium. They believe that if these portions are destroyed, the body will disappear by atrophy. This method, simple as it is, has not many strong adherents.

Finally, the weak galvanic current (2-5 milliamperes) has been tried and reported upon favorably by Sharkey (*Jour. Am. Med. Assoc.*, 1898, p. 634) and others. The claims made for it are: 1. It coagulates the blood in the vessels, causing disappearance of the vessels. 2. It produces mild adhesive inflammation, forming a cicatrix between the conjunctiva and the sclera. 3. It destroys micro-organisms in the tissues. While the galvanic current might be tried, its results are so uncertain that the method must be classed as unreliable.

Practically, at the present time, the best operations for pterygium are those of excision, (ablation or abscission), and those of transplantation, (deviation or burying). The principles of each are fundamental and established, and while the modifications of technic are innumerable, there are, nevertheless, but few things to be done in any pterygium operation.

Before describing in detail some of the more important operative procedures, it might not be amiss to discuss certain points common to all.

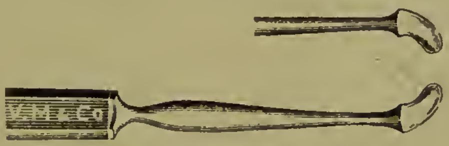
Preparation of the patient and for the operation. The time to operate is coincident with the first opportunity. Do not postpone operation until the head of the pterygium reaches the pupillary area, or "begins to interfere with the vision." Vision lost in this way can never be fully regained. Furthermore, there is a nebulous zone around the head of a pterygium reaching beyond its visible or apparent margin. Remember that a portion of the corneal epithelium and Bowman's membrane is to be removed, and left for a time unprotected, and that a very considerable portion of the conjunctiva is to be at least undermined. Infection under these conditions might be disastrous. Prepare the lids, lashes and conjunctival sac carefully, and in accordance with accepted methods of clean surgery. Do not operate in the presence of dacryocystitis or conjunctivitis with secretion. Local anesthesia is quite sufficient to render the operation painless. Cocain in 2 or 4 per cent. solution should be instilled in the usual manner. Solutions stronger than 5 per cent. are dangerous and no more effective. Adrenalin chloride, 1-3000, may be added to the cocain or used separately if desired. While the immediate effect of adrenalin is good, subsequent congestion and hemorrhage are sometimes more troublesome than primary hemorrhage. The latter is, as a rule, not very severe and can well be cared for by an assistant with a pledget of cotton or gauze.

The instruments required are not many. A good speculum, which will hold the lids firmly and permit of a wide, even exposure of the eyeball; a Graefe cataract knife or one of the specially designed knives for removing the head of the growth; a broad-toothed forceps; a small, blunt-pointed, straight scissors; a flat strabismus hook; a fine, sharp curette; a few small, curved needles, and some fine silk, are all that are necessary for any incision or transplantation operation.

Selection of method. This is more a matter of preference and judgment on the part of the operator, than a point to be determined by text-book rules. If the pterygium is very large and thick, the writer often prefers excision because the excess of tissue is in that way radically removed, and the result he thinks is apt to be smoother. If the pterygium is of moderate size, transplantation would be selected, and if very small, the method would to him seem immaterial.

In both operations of excision, and in those of transplantation, the head and neck of the pterygium must be carefully and completely removed. Ultimate success depends upon two factors, viz., complete removal of the head and neck from the cornea and limbus respectively, and the complete covering of all sclera exposed incident to the operation.

The head is best separated from the cornea by a sharp knife, although many operators prefer the method of evulsion by means of a flat strabismus hook as recommended by Prince (*Archiv. of Ophthalmology,* XIV, 16, 1885.) A Graefe cataract knife answers the purpose very well, but in a deeply-placed eyeball, it is at times difficult to manipulate so as to transfix the neck tangential to the surface of the sclera, and shave the head smoothly from the cornea by passing the knife forward. For this reason several useful knives have been specially constructed to better meet the conditions. H. B. Young, for example, has ground the angular keratome of Jaeger into a kidney or pointless sickle-shape, sharp all around. These knives are made right and left, and as the knife follows the contour of the globe, dissection is easier and cleaner.



Young's Pterygium Knife.

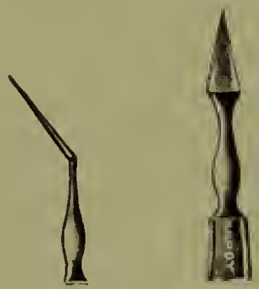
Melville Black prefers Agnew's iridectomy knife made about one-third size. The important point is to remove every vestige of the head, shaving down, if necessary, well into Bowman's membrane. Holmström (*Klin. Monatsblätter fuer Augenheilk,* XXXVIII, 1900, p. 550), for the purpose of securing less opacity of the cornea after operation, advises the method of abscising the cornea advanced by Malgaigne and Szokalsky (*Hygeia,* Bd. 61, 6. 229) for the removal of corneal opacities located in the superficial layers.

Evulsion of the head (Prince) is performed by introducing the tip of a strabismus hook beneath the neck, and then with moderate force dragging the hook forward with a prying motion, tearing the head from its attachment. A clean and complete separation is thought to be to the advantage of this method, but in the opinion of the writer, cutting when possible is always better than tearing in ophthalmic surgery.

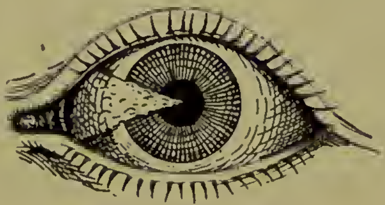
Cauterization and curetting of the corneal wound after the removal of the head have also been recommended. If the surgeon will be careful to have the corneal wound free and clean, it will make little difference which method of removal he adopts. The chances of recurrence will be minimized, and the after appearances of the eye enhanced, by careful attention to this detail.

The Drake-Brockman operation. The figures show the ordinary form of corneal pterygium seen in India and the operation which has been found effective for its removal.

The apex of the growth is picked up by a very fine pair of forceps (iris or similar kind) and stretched so as to ascertain its final attachment to cornea. While on the stretch a small nick is made in it close to the cornea. Into this opening is gently inserted one point of a small pair of very sharp scissors and the growth divided close to the cornea until the corneo-scleral margin is reached on the upper side. Then the scissors blade is placed on the lower end and the growth duly divided below to a point opposite to it above. This leaves a triangular tongue of membrane attached by its base to the conjunctiva. Now the conjunctiva under the growth is well undermined both above and below, so as to allow the portions of the conjunctiva at the corneal margin to be brought together easily when suturing. This having been done with the scissors, a cut is made through the growth at a sufficient angle, corresponding in size more or less to the part over the cornea and, ultimately, a diamond-shaped piece is excised and removed completely. (See figures.) A V-shaped opening now exists in the conjunctiva whose edges are sufficiently undermined above and below in order to adapt easily the incised edges which are then neatly brought together by two sutures. In the event of there being excessive tension after insertion of stitches, it is as well to incise the mucous membrane half way between the wound and inner canthus, as indicated by the

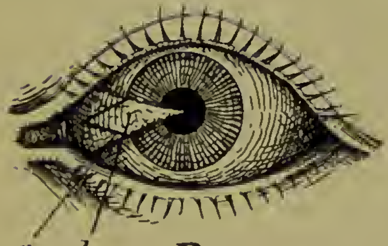

Agnew's Modified Iridectomy Knife.

dotted line. After completion of this portion of the operation it is as well to touch lightly with the electric cautery the portions of cornea to which the pterygium was originally attached, so as to prevent recurrence as far as possible. It is necessary for the prevention of hemorrhage, to inject a drop of adrenalin and cocain solution beneath the growth, and in order to obtain immediate union of the operative wound edges. Only very sharp instruments should be used in making the incisions. The electro-cautery is the most effective method of dealing with the corneal attachments of the growth, as being less likely to lead to patches of opacity, which are so often the result of operations for pterygium, especially when it is of long standing and much adherent to adjacent parts.



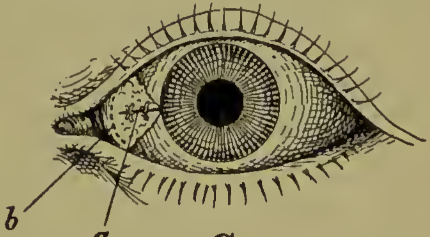
A

Pterygium Suitable for the Drake-Brockman Operation.



B

Drake-Brockman Operation for Pterygium. Exsection of Diamond-shaped Area.



C

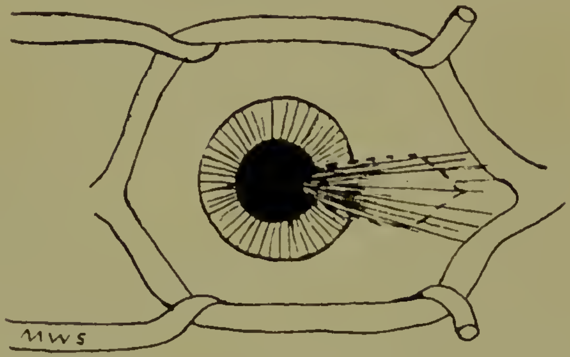
Final Stages of Drake-Brockman Operation for Pterygium.

The after-treatment consists in absolute quiet for the patient, and immobilization of both eyes to insure, if possible, healing by first intention, and to prevent the tearing out of the stitches. Two or three days will usually be sufficient time to keep both eyes bandaged, with an additional day or two for the operated eye. It is a mistake to keep an eye bandaged longer than absolutely necessary to secure a sufficiently firm union. Secretions accumulating back of closed lids do not aid in the healing process; it is better to flush the eye frequently with some cleansing solution, such as warm boric acid.

Stitches should be removed the moment they fail to be of service. Any stitch in the conjunctival sac is an irritant, and a loose, useless stitch is an unnecessary irritant. A careful inspection of the stitches from day to day should be made, and the time for removal determined by their efficiency, rather than by an arbitrary rule. Few stitches are active after five or six days; if union has not been secured in that time, the chances are the wound will have to heal by granulation. If this is recognized, then the sooner the stitches are out the better.

Reaction following operation for pterygium is usually not severe, nor is there much pain or discomfort following the operation. It is the practice of the writer to instill atropin or scopolamine immediately after any operation of this kind on the eyeball. Post-operative discomfort is lessened, irritability and lachrymation are diminished, and more complete relaxation is obtained. The eye is placed in the most favorable condition for repair.

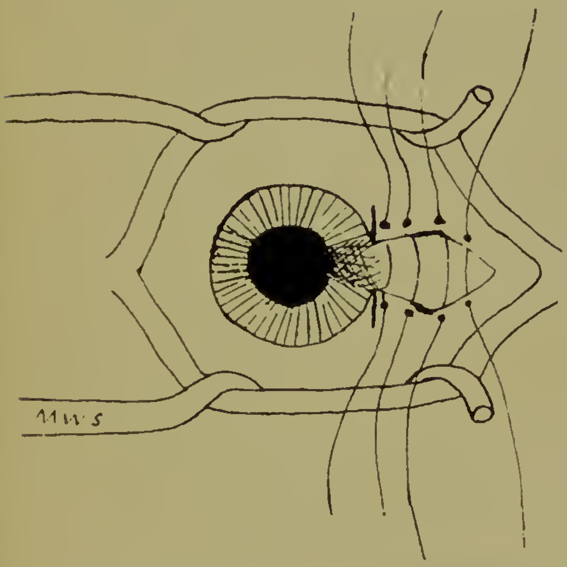
The after-results of this operation vary according to the size and extent of the pterygium removed, and the skill of the operator in the selection of method and execution. With a large pterygium, or one of moderate size, there will always be remaining an indelible opacity of the cornea just within the limbus, a more or less thickened and drawn, or rigid, condition of the conjunctiva in situ, and some yellowish discoloration, all of which appearances are far preferable and superior to those of the original condition.



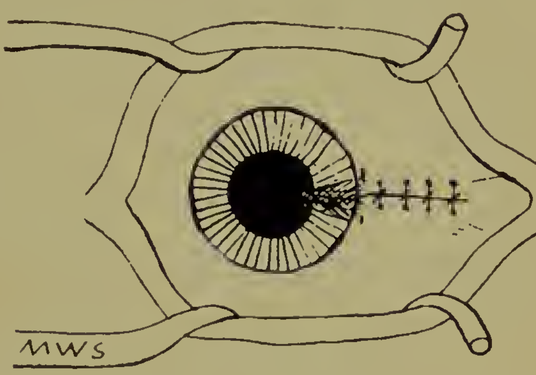
Arlt's Operation for Pterygium, showing the lines of incision.

Method of Arlt. Excision according to this method is one of the best and cleanest operations for pterygium, and gives, if properly done, a very satisfactory result.

After the usual preparations and the insertion of a blepharostat, or speculum, the neck of the pterygium is lifted from the eyeball by a broad-toothed forceps and transfixed with a Graefe knife parallel to the limbus at this point, and with the cutting edge directed toward the center of the cornea. By a sawing movement forward the head is cut from the cornea. If one of the other forms of knife be used, the technic is changed accordingly. The liberated head is then held in the forceps, and with a small, straight scissors, preferably blunt-pointed, the pterygium is dissected from its bed. The incisions above and below made by the scissors follow the margins of the pterygium backward toward the canthus (see figure), and are therefore divergent in this direction. They are carried backward about 6 or 7 mm., but the body of the pterygium is undermined much further—about twice this distance. Two converging incisions are then made with the scissors through the body of the pterygium to meet in the median line near the canthus. These latter incisions commence where the first two incisions terminated. A quadrilateral piece of the pterygium is thus removed, leaving a similar area of the sclera to be covered by conjunctiva drawn from above and below. (See fig.) It is well to undermine the conjunctiva above and below before introducing stitches to draw the two cut edges together. In this way undue tension is avoided and the result is smoother.



Arlt's Operation for Pterygium, showing scleral defect after removal of the "accommodation incisions," and the introduction of sutures.

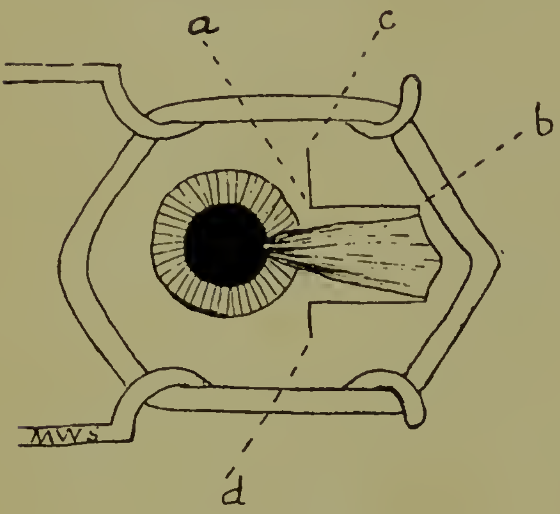


Arlt's Operation for Pterygium completed.

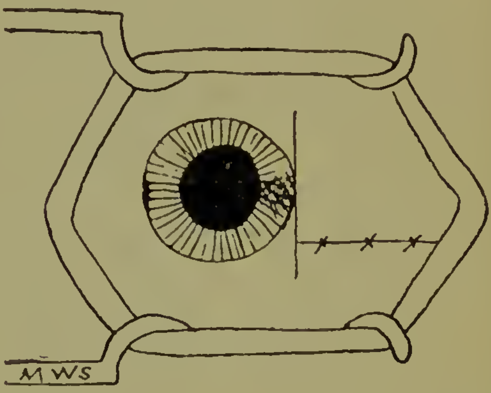
To prevent over-riding of the cornea when the conjunctival gap at the limbus is covered, two incisions several millimeters in length are made through the loosened conjunctiva at the limbus, one above and one below, tangential to the corneal margin, at the point of operation. These incisions have been well named "accommodation incisions." The number of stitches to be inserted will depend upon the size of the area to be covered. Suffice it to say that when the operation is completed an unbroken horizontal line of carefully stitched conjunctiva should extend from the margin of the cornea backward toward the canthus, and no part of the sclera should be left uncovered. The corneal wound should be treated as previously directed, and the rules for after-treatment observed according to the exigencies of the case.

If the pterygium were small, Arlt would often separate the head from the cornea, dissect a small portion only of the pterygium from the sclera, and unite the conjunctiva by several sutures at the limbus, or in front of the dissected portion. At times he would cut off the displaced tip, and sometimes he would leave it to atrophy and later disappear.

This procedure was also practised by Pagenstecher and often bears his name. The writer can see no advantage in this rather abortive modification of a clean-cut operation, and should the operator select Arlt's excision method, would recommend that it be done in its complete form.



Hobby's Operation for Pterygium, showing lines of incision.

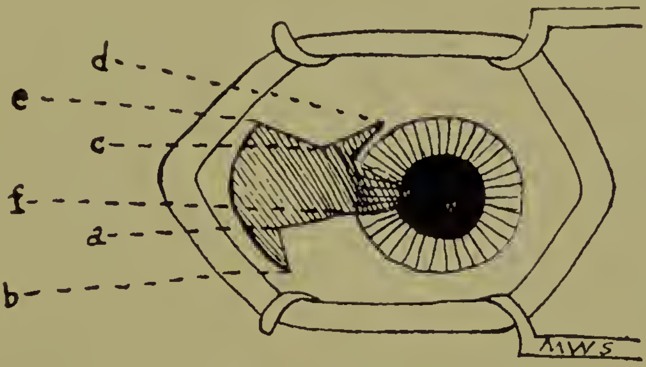


Hobby's Operation Completed.

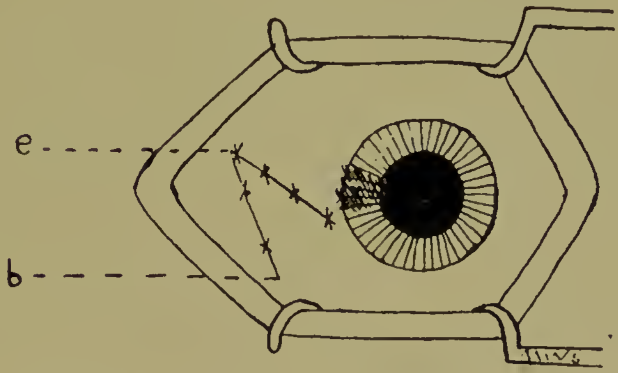
Hobby's excision operation. The conjunctiva is incised along the upper margin of the pterygium from the limbus to near the canthus. (See Fig.) A vertical incision is made extending from the margin of the cornea upward at right angles to the first (a.c.). The pterygium is then removed from the cornea, and the incision a.c. continued downward to a point a little below the inferior margin of the cornea. (d). An incision parallel to a.b. is carried along the lower margin of the pterygium. The pterygium is then dissected up and completely removed. The upper conjunctival flap is loosened from its attachments, drawn downward and united by several sutures, (Hobby inserts three) to the free margin of the lower flap. (*American Journal of Ophthalmology,* 1888, p. 94.)

The important claim made for Hobby's operation is that the line of conjunctival union is removed from the cornea, and from exposure in the palpebral fissure, and as recurrence after any excision operation is apt to take place in the cicatrix, the danger of recurrence is lessened.

Lipscomb's method of excision. P. Lipscomb has devised the following operation which has the advantage of total extirpation of the pterygium, and the placing of the cicatrix in a position not favorable for recurrence:



Lipscomb's Excision Operation for Pterygium, showing plan of removal and conjunctival defect.



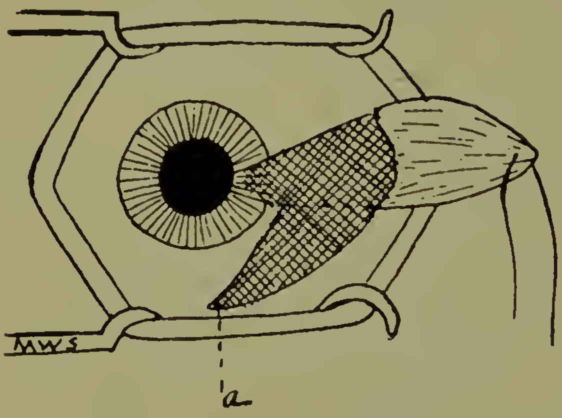
Lipscomb's Operation of Pterygium Completed.

The head is shaved from the cornea in the usual manner, and the body dissected free to its base, where it is removed with scissors. The conjunctiva below is undermined, and at the canthal portion an incision is made concentric to the corneal margin. (See Fig. a-b.) The conjunctiva above is likewise undermined, and an incision (c-d) made at the limbus. The conjunctiva is then united by sutures, by carrying a to e and c to f, and of course suturing at intermediate points. The line of sutures and the following cicatrix will thus lie obliquely as shown in the figure. Sutures may also be introduced along the line e-b if necessary.

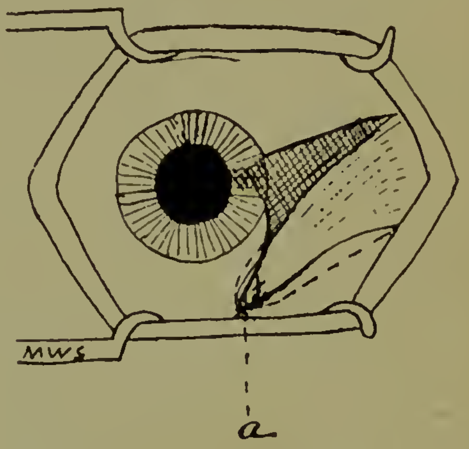
From the standpoint of plastic surgery, this operation is ingenious, and would seem to meet well the indications.

As a modification of technic applicable in any operation in which the pterygium is totally extirpated, G. Edgar Dean introduced the galvano-cautery snare. After freeing the pterygium from tip to base, the conjunctival defect is covered. The loop of the snare is then thrown over the extruded mass, and the pterygium is actually burnt off at its base. Dean has never known a pterygium to recur when treated in this manner.

Desmarres' method of transplantation. By this, the first practised transplantation method, the pterygium is separated from the cornea and its bed, back to its base. The tip is then transferred into a prepared angle or pocket in the lower fornix of the conjunctiva. After dissecting up the pterygium in the usual manner until it remains attached only at its base, an incision is carried downward toward the fornix through the conjunctiva, starting a few millimeters from the corneal margin. (See fig.) In to this denuded angle thus formed, the head of the pterygium is fastened with a single stitch.



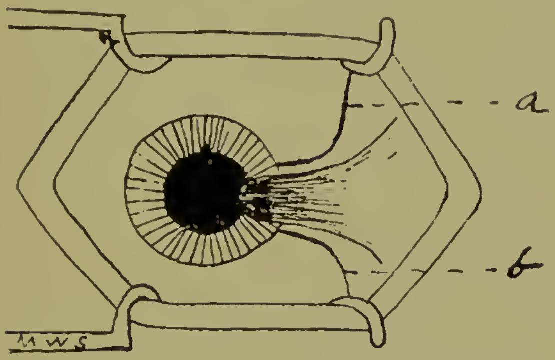
Desmarres' Transplantation Operation for Pterygium, showing Pterygium dissected back to its base, and prepared angle *a*, into which head is to be stitched.



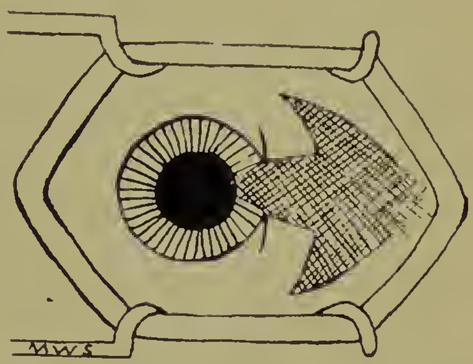
Desmarres' Operation, showing Pterygium transplanted into lower fornix.

Desmarres made no attempt to cover in the exposed sclera, but allowed the wound to heal by granulation. The operation is only described to show the origin of the transplantation method. It should not be performed to-day as Desmarres did it, as no surgeon would leave wounds to granulate that could just as well be covered. Important modifications, however, devised by Knapp and McReynolds, have made from this operative principle very effective methods of disposing of pterygium.

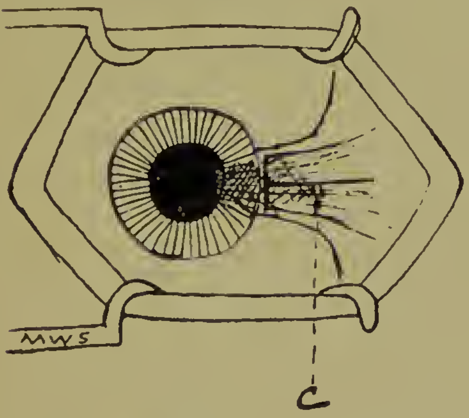
Knapp's operation. Knapp described his method as double transplantation and covering the defect with conjunctival flaps. The technic of the operation, following closely the author's own description (Norris and Oliver's *System*, III, p. 836), is as follows: Remove the head from the cornea. Incisions made with small curved scissors are then carried along the lower and the upper margins of the pterygium toward its insertion into the semi-lunar fold, and prolonged into the lower and upper fornix respectively. (See Fig., a and b.) The pterygium is then detached from the sclerotic and the head cut off. The conjunctival defect after the pterygium is dissected back to its base is shown in the figure.



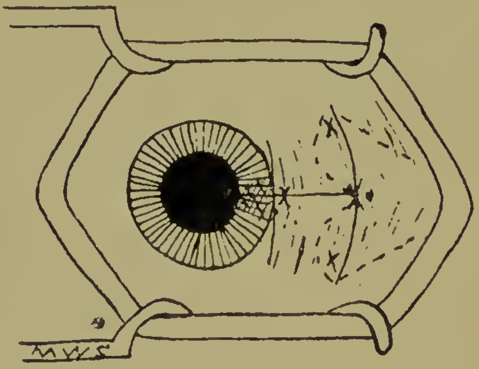
Knapp's Operation for Pterygium, showing primary incisions, *a* and *b*.



Knapp's Operation for Pterygium, showing conjunctival defect and "accommodation incisions."



Knapp's Operation, showing dissected pterygium split into symmetrical halves by incision, *C*.



Knapp's Operation Completed.

With a pair of straight scissors, the pterygium is then split into two symmetrical halves by a horizontal incision. The tip of the lower half is then stitched into the apex of the triangular defect in the lower conjunctival fornix, and the tip of the upper half is likewise stitched into the upper conjunctival fornix. To cover the defect, Knapp makes two "accommodation incisions" as shown in the figure, then introduces two stiches—one next to the limbus, and the other at the caruncular end of the defect. The latter stitch should, he says, include the tissue forming the apex of the angle behind the two halves of the split pterygium. The operation as finished is shown in the cut.

McReynolds' method. McReynolds, of Dallas, Texas, made in 1902 (*Jour. Amer. Med. Assoc.*, Aug. 9, 1902), a very important contribution to the surgery of pterygium. His operation, which is an ingenious modification of Desmarres' idea, possesses certain merits which have gained for it great popularity in this country.

It is easy of execution, no tissue is removed, unless perhaps it is the head of a large pterygium, and that is optional, no exposed sclera remains; the conjunctiva which covers the site of the pterygium is applied smoothly in its new position; if well done recurrence is exceptional; it is applicable to pterygia of any size, and it calls for but one stitch.

Transfix the neck of the pterygium with a knife, and shave the head smoothly from the cornea. Hold the tip of the pterygium with fixation forceps, and with slender, straight scissors divide the conjunctival and sub-conjunctival tissues along its lower margin from the neck to the canthus. (See Fig. a-b.)

Separate the body from the sclera with any small, non-cutting instrument, such as the closed blunt scissors, or a flat strabismus hook. Undermine the conjunctiva lying below the oblique incision made with the scissors. A pocket is thus formed into which the pterygium is to be buried.

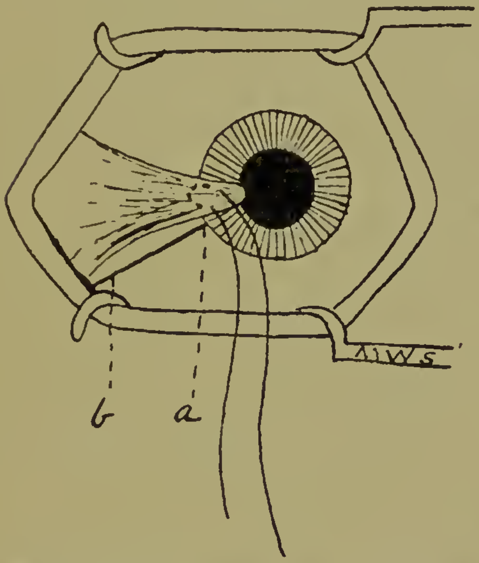
A black silk thread armed at each end with a small curved needle is passed through the apex of the pterygium, placing the loop on the under surface. The needles are then passed downward beneath the undermined conjunctiva, and brought out in the lower fornix, one about ⅛ or ¼ inch above the other, and both well over toward the vertical meridian of the cornea.

With these threads the pterygium is drawn downward into the sub-conjunctival pocket made for it. To facilitate this stage of the operation, the conjunctiva is at the same time raised with a forceps. The threads are then tightened, tied and cut. It is very important that no incision of any kind be made along the upper border of the pterygium. Such would cause a denuded space when traction was made upon the pterygium in drawing it into its new position.

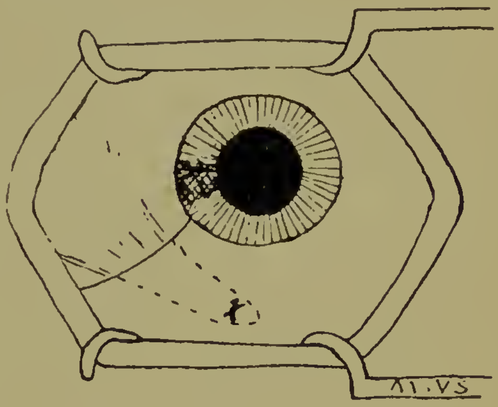
Beard urged as a practical suggestion in performing the operation, that the speculum be removed before proceeding to draw the pterygium into the prepared pocket. The effect of the speculum, he claimed was to greatly limit the extent to which the conjunctiva can be drawn downward, by pushing that membrane up into the fornix. The suggestion seems to be a good one.

Methods of Fox. Another method of transplantation practised and recommended by L. Webster Fox (*Diseases of the Eye,* 1904), is performed as follows: An incision is made in the conjunctiva along the upper and lower margins of the pterygium as shown in the accompanying figure.

The conjunctiva below is undermined or pocketed as far as the insertion of the inferior rectus muscle. The pterygium is then separated from the sclera with scissors, leaving, however, the corneal attachment intact. A double-armed thread is passed through the tip of the pterygium close to its corneal attachment. The head is then separated by a strabismus hook or knife, and carried into the newly formed cul-de-sac below. The needles are passed through the conjunctiva near the insertion of the inferior rectus muscle and tied, firmly holding the pterygium in its new position. The cut edges of the conjunctiva above and below are brought together with two or three stitches. Although no mention is made of it by Fox in his description, "accommodation incisions" at the limbus would aid in the replacement of the conjunctiva. The operation is simply an elaboration of Desmarres' original operation.



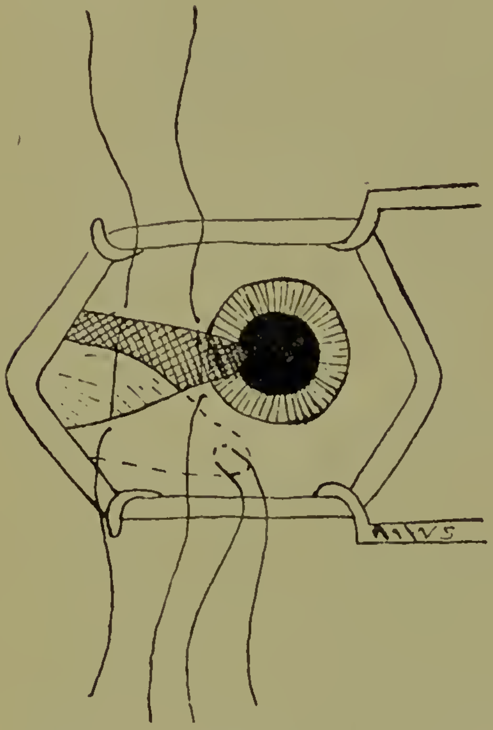
McReynolds' Operation for pterygium, showing incision (a-b), and the suture passed through the tip from within out.



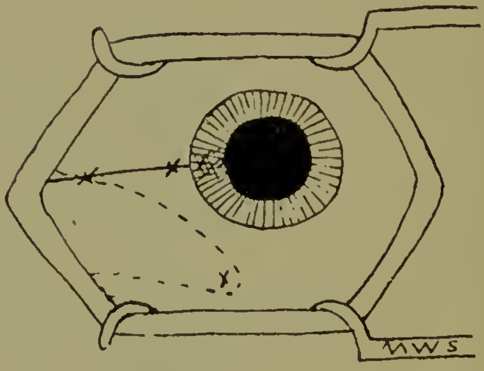
McReynolds' Operation Completed.

Subvolution or subinvolution of the pterygium. This method was practised by Galezowski (*Maladies des Yeux,* 1888.) The pterygium was separated from the cornea and sclera, and a double-armed thread passed through the tip. It was then doubled on itself by carrying its head beneath to be stitched to the base. Conjunctival sutures were introduced to cover the defect.

The same operation was later advocated by Bettman in this country, who gave to it the very appropriate name of subvolution or subinvolution. Bettman claimed that by thus placing mucous membrane against the sclera there could be no adhesion, consequently no recurrence.



Fox's Simple Transplantation of pterygium with conjunctival sutures.



Fox's Simple Transplantation of pterygium with conjunctival sutures. Operation completed.

Treatment by grafting. In dealing with very extensive pterygia, and especially with those that have undergone cystic degeneration or epitheliomatous changes, it is sometimes impossible to leave sufficient bulbar conjunctiva to properly cover the defect after removal. In such cases the surgeon may have recourse to mucous membrane grafts as described by Klein (*Allgem. Wiener med. Zeitung,* 3-4, 1876), or to Thiersch skin-grafts after the method of Hotz.

Hotz gave skin-grafts decided preference over mucous membrane grafts. They are more easily handled and fitted; they require no sutures; they grow better and shrink less; they are as smooth as the surrounding conjunctiva, but look paler and more whitish.

An epidermic graft a little smaller than the area to be covered is shaved from the arm or other suitable place and transferred directly to the denuded surface of the eyeball. It is carefully fitted and the eye dressed. The graft becomes adherent in about three days. The method of Hotz under proper indications has proven to be a valuable adjunct to the surgery of pterygium.

Having thoroughly cleansed the surface from which the graft is to be taken, a wide, sharp razor is drawn with a to-and-fro motion, removing the outer layers of the skin only. While most operators keep the razor flooded with warm sterile salt solution while detaching the graft, Beard held that the operation is greatly facilitated by having the skin and the razor perfectly dry.* The area to be covered must be free from blood before the graft is applied. The graft is transferred directly from the razor blade to the conjunctival defect, and there trimmed with scissors to properly conform. The lid is carefully closed so as not to displace the graft, and the eye dressed.

PSEUDO-PTERYGIUM AND RECURRENT PTERYGIUM.

The recurrent pterygium, it will be remembered, is not a true pterygium, but is, as a rule, a cicatricial structure. Occasionally, after removal or repeated removal of pterygium, a sclerotic degeneration of the cornea takes place, resembling very much what is known as keloid-cornea. In an exaggerated form the movements of the eyeball may be restricted, or the eyeball may be drawn into strabismus. It is the advice of Knapp, Beard and others not to interfere in these complicated cicatricial conditions unless it is absolutely necessary. Gifford (*Ophthalmic Record,* Jan., 1909), on the other hand, says that his experience indicates that all of these bad cases of recurrent pterygium can be cured if a large enough Thiersch flap or epithelial lip-flap is put on. He further says: "In doing the operation, it is important, in dissecting back the conjunctiva, to clean the cornea and sclera very thoroughly, and to be sure that the flap is well attached to the globe before the lids are allowed to close. The devices which I have adopted of fixing the globe in position of abduction by means of a guy-thread put through the tendon of the external rectus and fastened to the skin outside the external canthus with collodionized gauze to prevent displacement of the flap, may be necessary in some extreme cases. But if the flap is pressed down firmly with an absorbent cotton toothpick swab, slightly moistened, so as to bring the entire under-surface into close contact with the globe, and the lids are held open for three to five minutes thereafter, then both eyes kept closed with a rather firm bandage, with plenty of cotton, for 48 hours, failures from displacement of the flap will be rare. In applying the latter it is sometimes necessary to tuck the edges in under the loosened conjunctiva, and I have once or twice protected the well-applied flap by temporarily drawing the conjunctiva partly over it with a suture. The flap should be slid directly from the razor to the globe. It should be cut large enough, and, after covering the defect on the globe, the excess on the temporal side is trimmed off so as to leave bare the cornea, and a strip of sclera about 1-16 inch wide between it and the flap.''

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* [Keeping the razor well covered with warm, sterile vaselin, after the suggestion of Walter Parker, gives still better results.—*Ed.*]

Surgical procedures for the relief of these distressing conditions other than grafting, are well summarized by Beard, who says:

''In its surgical treatment, false pterygium involves many of the principles which are concerned in operations for symblepharon as well as most of those described in connection with the true form: No set methods can be laid down for their operative handling, as they present so great a variety that each case must be separately reckoned with.'' —(W. T. S.)

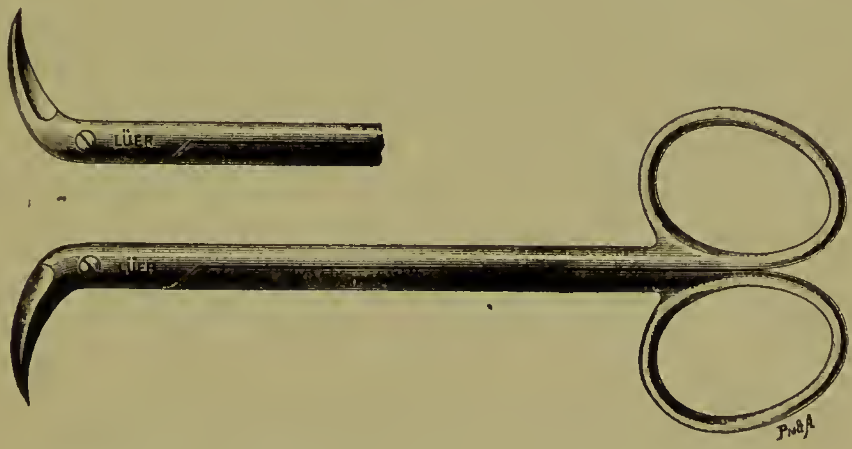
In addition to the principal operations just described a number of others, as well as later modifications of some already published, are depicted in more or less recent literature. A few of these are indicated as follows.

Cabannes (*La Clinque Ophtalmologique,* Dec., 1908) has reported a new operation whose principle is founded on three considerations. (a) To excise the smallest quantity of pterygium possible; (b) not to include the pterygium in the conjunctival suture, but to exclude it; (c) to re-cover the bed of the excised pterygium by the neighboring healthy conjunctiva, without traction on that membrane. For these reasons he describes his method as a procedure by exclusion of the pterygium, with conjunctival suture by gliding. The following are the steps of the operation.

First, the head of the pterygium is detached and the pterygium dissected deeply as far as its centre. If small it is not excised, and if larger only the part covering the cornea is resected. The pterygium is now drawn towards the caruncle by means of forceps held by an assistant. The cornea is carefully scraped with a curette or touched with a cautery. The eye is carried outwards and the bed of the pterygium is freely exposed, whilst the latter, left to itself, retracts in a ball towards the inner angle; it will remain there and is not touched again.

The second step consists in covering the bed of the pterygium with healthy conjunctiva. The conjunctiva is detached from the corneal margin above and below as far as the vertical meridian, at which level a vertical liberating incision is made, one to one and a half cm. in extent. By dissecting up the areas thus marked out two conjunctival flaps are obtained, somewhat quadrangular in form, the one superior, the other inferior, and are easily brought without traction over the bed of the pterygium.

Thirdly, the borders of the conjunctival flaps are brought together by two connecting sutures: the one nearest the cornea ought to extend into the episcleral tissue. The stitches are left in place for six or seven days and then removed when the cicatrization is perfect. The pterygium, retracted towards the caruncle, has withered. The eye remains red for about three weeks or a month and the cure is then complete. This operation has given Cabannes constant and lasting results. (E. M. Lithqon in the *Oph. Review,* p. 145, May, 1909.)



Chadwick's Scissors with Double Curve for Pterygium.

Uribe y Troncoso (*Annales d'Oculistique,* vol. 152, August, 1914), describes his favorite operation as follows: Seizing the head of the pterygium with fine forceps, take a fine bistoury and carefully detach the head cleanly from the cornea, dissecting down to the sclera for 3mm. beyond the edge of the pterygium. With a fine curette scrape the bared corneal and scleral surfaces along the edges of the growth. After the head is once detached replace it and with fine scissors make a vertical incision, chord-like, across the neck of pterygium to remove all this separated triangle. Whenever this is done the ocular conjunctiva retracts strongly, leaving a semi-circular bared area. At the inner curved margin of this area make a short snip in an upward and inward direction, length about 2-3 cm. according to loss of substance entailed, including both conjunctiva and episcleral tissues. This incision is then continued in an oblique line, longer where a larger flap is needed, upwards and slightly outwards so that the base of the flap thus made is considerably longer than the 2-3 mm. side of flap. Dissect up this flap with its episcleral tissue and slide it around towards the limbus so that the semi-circular part comes close up to the inner limbus, where it is securely sutured, another suture being put in at the angle of the flap and another two further up-in. Remove sutures on the sixth day; expect to find flap swollen considerably, but this swelling disappears within four to six weeks.

Troncoso says that the operation can be readily done and that it gives better results, but the conjunctiva must be healthy to start with. [*Oph. Review* abstract, May, 1915.]

The *Ophthalmoscope* (1915-1916) also gives in abstract a number of new or modified methods of operating on pterygium. Among these is the procedure of Terson (*Archives d'Ophtalm.*, March, 1911). The writer differentiates two types of pterygia, namely, pterygium complete or the centripetal form, and a second more benign and, so to speak, centrifugal form. In pterygium complete, in addition to the elements usually found, there may be added a vascular development, sometimes very intense, giving an angioid aspect and suggesting an angio-fibroma. These are clinically neoplastic, and constitute a tumor, they grow like a tumor, and must be operated on as a recurrent tumor.

The so-called centrifugal form is one in which the pterygium is triangular, with its base to the cornea, which does not encroach upon that structure. In such Terson has only found a bandelette of sclerosed, and but little vascular, tissue. It grows only by its being continually nipped between the lids.

The etiology of pterygium is far from satisfactory, for whilst noting the frequency of its occurrence in dusty trades, the author has also met with it in hall-porters, teachers, etc., and in occupations with but little chance of exposure to physical agents. He considers, nevertheless, that amongst subjects predisposed to the condition, physical agents constitute the chief cause of the lesion, and suggests that the sclerosing process which takes place, may be compared with the condition which obtains in Dupuytren's contraction of the palmar fascia.

The arthritic and gouty diatheses, especially with chronic alcoholism, are also factors, and, as with pinguecula, there appears to be in some families a hereditary tendency to the disease.

With Brault's theory in mind as to the presence of glycogen in tumors, from the point of view of prognosis, Terson has searched for this substance in large pterygia, but has been able only once to obtain some evidence of its existence.

Terson's operation is as follows.—Under cocain and adrenalin, the pterygium is seized at a reasonable distance from the caruncle with fixation forceps such as are usually employed for cataract extraction; incisions are made with narrow, sharp scissors, and should form three sides of a rectangle; the fourth side, horizontally placed and below, is not cut, but forms the base of a flap of conjunctiva, which is afterwards used to cover the area denuded by being sutured to the upper horizontal edge of the wound. The head of the pterygium is removed by dissecting carefully with a fine scalpel, using that part of the blade close to the point, rather than the point itself, in order to avoid leaving behind débris. The underlying corneal stroma is lightly curetted, until it appears as transparent as possible, without going too deeply, and is finally cauterized with the galvano-cautery. The pterygium is then removed and the wound closed by drawing up the conjunctiva from below, approximating it to the upper horizontal line of incision. Sutures, usually about three, of fine silk (000) or of finest reindeer-tendon, are used to fix the flap, and should be placed deeply enough to involve the sclera.

The silk sutures will cut out after the sixth day, or if not, should be removed, although not all at the same time; those of reindeer-tendon are left slowly to absorb. Both eyes are covered for three days.

The chief advantages claimed for the operation rest in the fact that the sutures lie protected by the upper lid, and that a new area of conjunctiva is brought up to take the place of that occupied by the pterygium. The immediate result is stated to be very satisfactory. The author has records of cases of five or six years' standing without a recurrence. If such takes place in the cornea, and does not yield to yellow ointment or Darier's mercurial lanoline, simple and careful curetting, repeated at long intervals, will often suffice to keep the lesion in check.

For the large invading pterygia, if electrolysis and fibrolysin have been unsuccessful, radio-therapy, more particularly radium, should be tried, and, failing these means, a plastic operation similar to that which may be necessary in symblepharon, should be considered.

G. A. Cazalis (*La Clinique Ophtalmologique*, Sept., 1914), describes his operation as follows: The pterygium is detached pretty much in the usual way, the basal incision not being carried too far back. The bed of the growth is then most scrupulously cleared of all tags of tissue by curetting, cauterizing, and then apparently scraping again with a very sharp knife, used after the manner of a plane. After this the upper conjunctival region is raised in the form of a flap by two incisions parallel with the corneal limbus. The corneal edge of this flap is then turned in so as to make a hem which shall face the cornea instead of a raw surface facing the cornea. The flap is next carried well down below the level of the still attached lower portion of the conjunctiva, and therefore well below the original attachment of the pterygium, and stitched there. According to the author, this operation is a safeguard against relapses.

Pterygium carnosum. PTERYGIUM CRASSUM. A thick, vascular, muscle-like form of the disease.

Pterygium cyst. Motolese (*Ophth. Year-Book,* p. 120, 1913) has studied histologically a cyst in a pterygium. The growth, which extended almost to the pupillary margin, contained a cyst of the size of a hemp seed, and straddled the limbus. The posterior wall of the cyst was adherent to the cornea and episclera. The connective tissue of the pterygium was rich in plasma cells. The main cyst was lined with endothelium. Adjacent to it was a smaller cyst, which apparently consisted of a dilated glandular tubule, and was lined by two layers of epithelial cells—a superficial one of cylindrical cells and a deeper of cuboidal cells. See, also, **Pterygium.**

Pterygium, Familial. This is a very rare occurrence, but Armaignac (*La Clinique Ophtalmologique,* July, 1914), gives the following history of twenty-two persons in three generations. Of these, nine have either been lost sight of or died in infancy. Of the remaining thirteen, eight have or have had pterygium. The proportion may yet become greater as the third generation grows up. At least two out of the eight had quadruple pterygium. It has not been possible to attribute the occurrence of these cases to any of the ordinary causes, and Armaignac is convinced that it is a case of hereditary transmission of a blemish of anatomical, pathological, or cosmetic character, such as one sees so often, and of which the real nature remains profoundly mysterious.

Pterygium membranaceum. (L.) Pterygium tenue.

Pterygium pingue. Pinguecula.

Pterygium tenue. The thin, generally old, atrophic form of the growth.

Pterygium sarcomatosum. Same as pterygium carnosum.

Pterygium vasculosum. Pterygium carnosum.

Ptiloma. The bared part of the eyelid caused by ptilosis.

Ptilosis. MADROSIS CILIARIS. ALOPECIA CILIARIS. A falling out or loss of the eyelashes.

P. T. O. Abbreviation for Ger. Perlsucht tuberculin original, or Klemperer's tuberculin.

Ptomaines, Oculotoxic effects of. Botulism. Allantiasis. It has been known for a very long time that food which has undergone putrefaction may, under certain circumstances, act as a violent poison, setting up severe catarrh, and producing symptoms of a more general nature. Stale mussels, fish and sausages have even a popular reputation on account of their poisonous qualities. A ptomaine was first obtained by Marquardt in 1865, and described by him as similar to conine; in 1869 Sülzer and Sonnenschein isolated a crystallizable ptomaine which resembled in its qualities atropine and hyoscyamine. Of recent years attention has been called to this question from another point of view, and one of special interest to the medical jurist. At a trial at Rome, on the occasion of a supposed murder, a material was extracted from the body which had markedly poisonous qualities, similar to those of delphinine. It was supposed by those who undertook the prosecution that this poison had been administered to the deceased, but on the side of the defense it was pointed out that the extract, though similar in some respects to delphinine, was in others quite distinct, producing on the frogs heart very different effects.

Attention having been called to the subject, scientific investigators, especially those of Italy and Germany, busied themselves in extracting these poisonous materials, ptomaines (Gr. ptoma, "a corpse"), from putrescent animal matters, and investigating both their chemical and physiological properties. These ptomaines can hardly be said to form a very distinct group of bodies from a chemical point of view, for some, like putrescine and cadaverine, are amines; others are amido-acids, like creatinin, and neurine, which has choline and muscarine closely allied to it, is trimethyl-vinylammonium-hydroxide. It cannot even be said to possess an alkaline reaction, at one time supposed to be a common property of all ptomaines, and one which related them to the vegetable alkaloids, for Salkowski showed that creatinin, a body that has been long known and apparently carefully investigated, when obtained pure gives no reaction with litmus-paper, nor does it possess the power of combining with acids like a base. Brieger, who first showed that alkaloids were formed by bacteria under a variety of conditions, and that some of them were poisonous, subsequently recognized that though organic bases may be formed and may be toxic, the important toxins do not belong to that category; rather was it probable that the extra-cellular toxins of diphtheria, tetanus, and other such diseases were of proteid nature. (*Standard Encyclopedia.*)

The effects of acute ptomaine intoxication on the eye are marked and quite definite. The subject is fully treated under **Toxic amblyopia.** See, also, **Fish poisoning**, p. 5208, Vol. VII of this *Encyclopedia.*

Bull (*Prac. Med. Series,* Eye, p. 124, 1907) has reported two cases of choroidal lesion due to ptomaine poisoning. The first, of a girl of 14, had been seriously ill with vomiting, diarrhea, increased temperature, rapid pulse and profound prostration and delirium. Large pemphigoid bullæ appeared on the trunk and extremities. Six weeks after the attack her eyes were examined. The pupils were dilated, iris immovable, and total paralysis of the accommodation. Optic nerves pale. Scattered all over the fundus of both eyes were patches of yellowish-white exudation in the choroid of varying size and shape, very flat, with scarcely any elevation above the general fundus. They were in different stages. The older patches were surrounded by a reddish margin, but there were no pigment masses anywhere. There were no scotomata and no limitation of the field of vision. The ophthalmoscopic picture did not suggest syphilis and no history of it was obtained. The patient got well under iron, strychnia and arsenic. The second case was in a young lady of 27. The attack of poisoning was similar to the other. The eye findings, too, were quite the same as in the first case, with the addition of some faint peripheral striæ in both lenses. In this case also there was no hint of syphilis. She was at first put on mixed treatment, including inunctions, but owing to the anemia this was charged to iron and arsenic, which were given later with strychnia. This case also recovered; even the opacities in the lenses disappeared.

Ptosed. Affected with ptosis; prolapsed.

Ptosis. Drooping of the upper eyelid. This condition should be studied only after a careful perusal of the anatomy and histology of the eyelids. See p. 342, Vol. I, as well as p. 5944, Vol. VII of this *Encyclopedia.* For readier reference to the various sub-captions of this section the following list is presented, and the subjects will be discussed in the order given: Acquired ptosis—Pseudo-ptosis—Treatment—Hunt's operation—Operation of Dransart—Operation of Pagenstecher—Mules' operations for ptosis—Worth's operation—Harman's operation—de Wecker's operation—Operation of Hess—Landolt's operation for ptosis—Operation of Panas—Allport's modifications of Panas' operation—Grimsdale's modifications of Panas' operation—Tansley's operation for ptosis—Operation of Rollet for ptosis—Operation of Darier—Operation of Fergus—Operation of Angelucci—Operation of Sourdille—Bowman's operation for ptosis—Operation of Eversbusch—Snellen's operation—Wollf's operation for ptosis

—Operation of Lapersonne—Elschnig's operation for ptosis—Operation of Gillet de Grandmont—Beard's operation for ptosis—Wilder's operation for ptosis—Operation of Motais—Parinaud's operation—Summary.

Congenital ptosis. This anomaly is sometimes hereditary. It usually affects both upper eyelids and is frequently associated with other defects, such as weakness of the superior rectus, squint, microphthalmus or epicanthus. In congenital ptosis there may be defective development or complete absence of the levator muscle and this may be associated with an inability to look upward, owing to defective innervation, imperfect development or absence of the superior rectus.

Cases of congenital, mostly unilateral, ptosis have been observed in which the lid cannot be elevated in the natural manner, but as soon as the patient opens the mouth or moves the lower jaw to one side or the other, the lid is raised completely, and remains so until the action of the jaw is discontinued. See **Jaw-winking.**

Acquired ptosis. This condition is due either to some injury of the levator or to a lesion of the nerve or nerve center supplying it. As the levator palpebræ is supplied by a branch of the third nerve, ptosis frequently accompanies paralysis of other ocular muscles supplied by this nerve. The lesion may be either in the trunk of the nerve, in its nucleus or, possibly, in the cortex of the cerebrum.

A slowly-appearing, progressive, partial ptosis is sometimes observed in women about the time of the menopause, or in elderly people, that is probably due to a form of atrophy of the levator.

Pseudo-ptosis. Drooping of the lid occasioned by swelling from edema, tumors and elephantiasis should not be classed with cases of genuine ptosis. So, too, the slight drooping of the lid so frequently seen in trachoma is due more to the additional weight of the lid, combined probably with paresis of the muscle of Müller.

The condition known as *ptosis adiposa* is the result of a relaxed skin which hangs down like a fold over the free border of the lid, and becomes more noticeable when the lid is drawn upward. This is due to the lack of rigidity of the fascial fibers of the levator tendon, that pass forward between the bundles of the orbicularis muscle to be attached to the skin of the eyelid.

All of these forms should be classed under the head of pseudo-ptosis in contradistinction to true ptosis, operations for which are here to be considered.

In cases of complete ptosis, the cornea is covered and vision is impossible unless the lid is raised either with the hand or with some mechanical appliance such as a spring attached to a spectacle frame.

In double partial ptosis, the patient's head takes a characteristic backward pose to enable him to look under the lid border, and at the same time the forehead is wrinkled and the eyebrows raised in an attempt to aid the weakened levator by the action of the frontalis.

Treatment of the various forms of ptosis. The treatment of ptosis will depend upon the nature of the trouble. Some cases of acquired ptosis may be relieved by non-operative treatment.

Frequently paralytic ptosis has a syphilitic origin, and may be remedied by appropriate anti-syphilitic measures, if treatment is begun in time. If this is unsuccessful, the advisability of an operation will be determined by the degree of the ptosis, and whether or not it is associated with paralysis of some of the other ocular muscles. If the latter, it may be better to let the drooping lid remain rather than to raise it by an operation and so subject the patient to an annoying diplopia. Electrical treatment, massage, and other measures should be tried before resorting to operation in such cases.

Numerous mechanical devices have been used at various times to hold up the drooping lid, and in late years Goldzieher (*Centrabl f. prak. Augenheilk.*, 1890, p. 34), Kauffmann (*Centralbl. f. prak. Augenheilk.*, March, 1893) and Meyer (*Archiv. f. Augenheilk.*, 1893, Vol. XXVI, 2, p. 153) have revived this form of treatment. The support for the lid is generally attached to some form of spectacle frame, adjusted to suit the individual case. Such expedients are merely temporary, and need only be alluded to in this connection.

In traumatic ptosis due to division of the levator or its tendon from a wound of the eyelid, the divided ends of the muscle or tendon should be carefully searched for and reunited by catgut sutures, before the wound in the lid is closed.

In the congenital forms, the advisability of an operation will depend upon: 1st. The degree of the deformity. 2nd. Whether bilateral or unilateral. 3rd. Condition of the sight and of the ocular muscles of the affected eye.

Naturally, if the ptosis (of one lid or both) is slight and is not enough to interfere with vision of the eye, the only reason for an operation would be a cosmetic one. The same might be said of complete, unilateral ptosis of a markedly amblyopic eye, or of one whose extrinsic muscles are so affected as to prevent binocular single vision if the lid were raised.

The question of the best operative procedure in cases of ptosis, in which operation is deemed advisable, will depend largely upon the degree of power still remaining in the levator palpebræ. If the muscle still retains some degree of power in raising the lid this may be increased by so changing its point of insertion in the lid that it may act to better advantage. If, however, this muscle is powerless, as it is frequently in complete congenital ptosis and in some of the paralytic cases, recourse will be necessary to those forms of operation which aim to raise the lid by substituting for the levator the action of other muscles. It is, therefore, extremely important to determine not only the exact nature of the deformity, but the relative strength of the levator. The former can usually be done by the history of the trouble and the degree of it. The latter can be easily determined, as suggested by Grimsdale and Brewerton (*A Text Book of Ophthalmic Operations,* 1907, p. 53), by firmly depressing the eyebrow of the affected side so as to control the power of the frontalis muscle upon the lid, and then noting, when the patient is asked to open the eye, whether there is any motion of the lid upward. If so, it is evidence that the levator is still active.

The numerous operations that have been devised for ptosis is evidence of the difficulty in satisfactorily correcting this condition. In considering these various methods the following classification has been adopted, partly because it indicates somewhat the chronological order in which the various procedures were developed, and also presents first for description those which aim to correct the severer forms, viz.: complete ptosis, with entire or almost entire loss of power of the levator palpebræ. It will be seen that some of the operations combine operative principles in two or more groups. The classification follows very closely that of Grimsdale and Brewerton.

CLASSIFICATION OF OPERATIONS FOR PTOSIS

Class 1. Shortening the lid by excision of the skin.

(Methods of)
Arabian surgeons
Scarpa;
Graefe.

(Modification by)
Hunt.

Class II. Substituting the action of the frontalis muscle for that of the levator palpebræ.

Group a. By means of sutures.

(Methods of)
Dransart
Pagenstecher.

(Modification by)
Dehenne;
Gayet;
Birnbacher;
Mules;

Worth;
Harman;
de Wecker;
Landolt;
Hess.

Group b. By flaps of skin.
(Methods of)
Panas

(Modification by)
Tansley;
Allport;
Grimsdale;
Rollet;
Darier.

Group c. By attaching a flap of the frontalis muscle to the lid.
(Methods of)
Fergus.

Group d. By attaching the tendon of the levator to the frontalis.
(Methods of)
Angelucci.

(Modification by)
Sourdille.

Class III. Advancement of the point of insertion of the levator palpebræ.

Group a. By partial excision of the tarsus and levator tendon.
(Methods of)
Bowman.

Group b. By folding the tendon.
(Methods of)
Eversbusch.

(Modification by)
Snellen;
Wolff;
Lapersonne;
Elschnig.

Group c. By excision of a strip of the tarsus.
(Methods of)
Bowman;
de Grandmont.

(Modification by)
Nicati;
Boucheron;
Gruening;
Theobald;
Fergus;
Mayou.

Combination of the principles of classes II and III.

(Methods of)
Beard;
Wilder.

Class IV. Substituting for the action of the levator that of the superior rectus.

(Methods of)	(Modification of)
Motais;	Shoemaker;
Parinaud.	Wilder.

CLASS I. SHORTENING THE LID BY EXCISION OF THE SKIN.

According to Valude (*Encyclopédie Française d'Ophtal.*, Vol. IX, p. 141), the ancient Arabian operators treated ptosis by excising a piece of skin from the lid sufficiently large to effect the necessary shortening. Scarpa followed the same practice, but observed that if the skin were removed from the lid near the eyebrow the effect was even more pronounced.

Hunt (*London Med. Gazette,* Vol. VII, 1830, p. 361), recognized the principle that not only is the levator palpebræ used in raising the lid, but part of the frontalis as well. He states that "it is almost impossible to draw the eyebrow upward when the eye is kept completely closed, and equally difficult to depress the eyebrow while the eye remains wide open," and that "the anterior fibers of the occipito-frontalis inserted into the superciliary integument prevent the levator from drawing the eyelid too far backward."

Hunt's operation. A curved incision just below the line of hairs of the eyebrow is made through the skin, extending from a point over the inner angle of the lids to one the same distance above the outer angle. This incision is joined at either end by one made parallel to the lid margin and at a sufficient distance above it to obtain the desired degree of elevation of the lid. The skin between these incisions is then dissected away, leaving the fibers of the orbicularis intact, and the edges of the wound are united with sutures. The effect is to bring the skin of the lid in contact with that part of the skin of the brow on which the frontalis acts. The operation is applicable only to those cases in which the levator is paralyzed.

This is, in effect, the principle upon which are based the operations to be described under Class II, and naturally leads up to them. As will be seen later, Tansley modified this operation. Graefe (*Archiv. f. Ophthal.* Vol. IX, 2, p. 57), made an incision the length of the lid, through the skin and about 4 or 5 mm. from the free border. Separating the lips of the wound, he then excised a strip of the orbicularis, 5 mm. wide, down to the tarsus and levator. If there were a redundancy of skin, he also excised a narrow strip of it, after the manner of the ancient surgeons, and then brought the lips of the wound together with sutures which he passed through the skin and the edges of the divided muscle. He thus aimed to get a subcutaneous shortening of the lid and a weakening of the orbicularis, to offset the weakened levator.

All of these methods naturally fell into disuse because the shortening of the lid prevented proper closure, and ulceration of the cornea from lagophthalmus so frequently followed.

CLASS II. SUBSTITUTING THE ACTION OF THE FRONTALIS MUSCLE FOR THAT OF THE LEVATOR PALPEBRÆ.

Group a. By means of sutures.

Dransart (*Annales d'Oculistique*, 1880, Vol. 84, p. 88), was probably the first to apply by means of sutures the principle first enunciated by Hunt, but the procedure of Pagenstecher, next to be described, was proposed nearly at the same time.

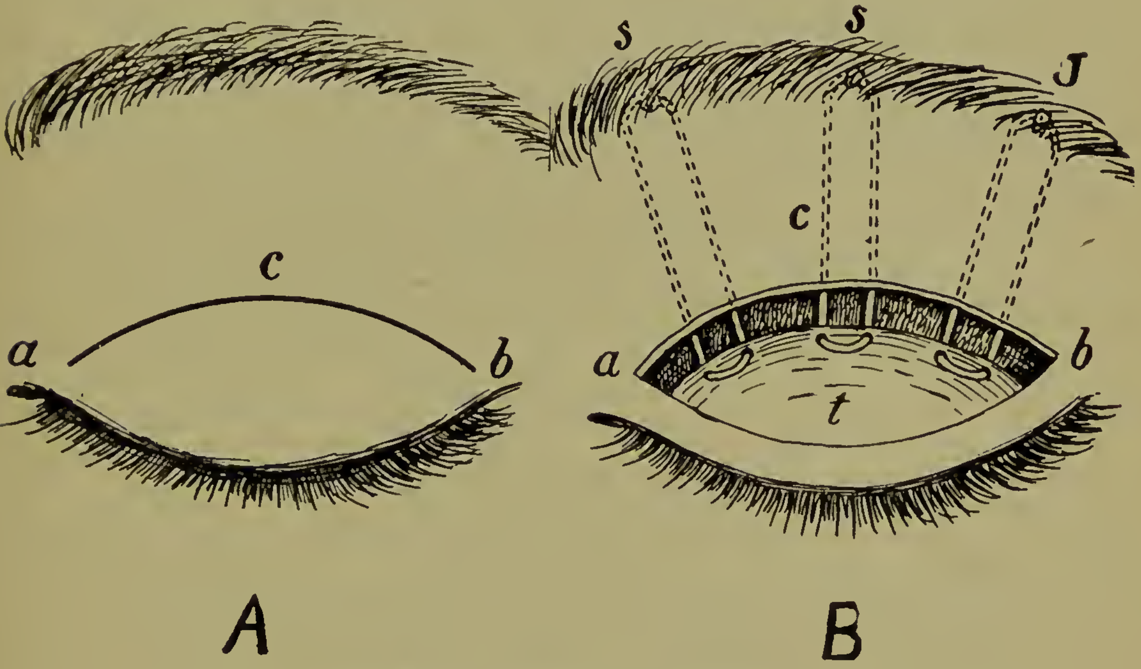
Operation of Dransart. An incision in the skin of the upper lid is made along the length of the superior border of the tarsus exposing it. The skin of the upper flap is next separated, by dissecting up to the muscle overlying the eyebrow, so as to expose the upper part of the orbicularis. Then a loop-suture of catgut, armed at each end with a needle, is passed through the middle portion of the superior border of the tarsus, the needles passing from the superficial to the deep surface and emerging again immediately above the tarsal border. The needles then pass through the cellular tissue and muscle under the eyebrow.

In the same manner a similar suture is passed, at a distance of 6 mm. or 8 mm., on either side of the middle one. (See the figures.) The sutures are tightened sufficiently to elevate the lid, and the ends are cut short near the knot. After the bleeding has ceased the flap of skin is replaced and the wound united with superficial sutures.

As a result of the operation, there are formed along the line of the buried sutures, strands of connective tissue that connect the frontalis muscle directly with the lid and thus assist in raising it.

Operation of Pagenstecher. This operation also aims to establish a connection of the frontalis with the lid by means of sutures and bands of cicatricial tissue.

Two double-armed sutures of silk are passed in the following manner: One needle enters the skin of the lid at a point 2 mm. above the free border and 7 mm. or 8 mm. from the angle of the lid, a. It traverses a course beneath the skin to emerge just above the eyebrow at b. The other needle, on the same suture, enters the skin at the point of puncture of the first, a, and passes under the skin in a line parallel to the free border, to emerge 3 mm. distant at a point, c. It is then reinstated at the same point as it emerged, to traverse a course beneath the skin parallel to that of the first and to emerge above the brow at a point, d, 3 mm. from the first. There is thus placed a subcutaneous loop. (See the illustration.)



Dransart's Operation for Ptosis.

A. Incision, *a*, *b*, made along the line of the superior border of the tarsus, exposing it. Flap *c*, of skin, is then separated from the muscle up to the eyebrow.

B. Loop-sutures, s. *s*, J. of catgut pass through the upper border of the tarsus, *t;* then under the skin flap, *c*, and are attached to the muscular tissue under the eyebrow.

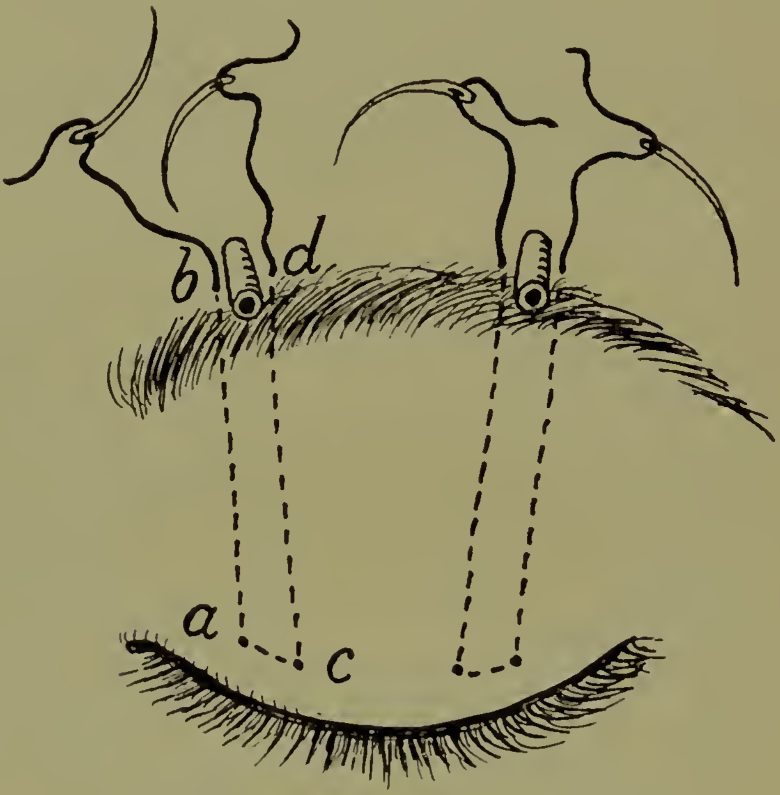
In a similar manner the second suture is passed about 8 mm. from the other angle of the lids. The two sutures should not be exactly vertical, but should be somewhat farther apart above the brow than at the lid border. The sutures are then tightened sufficiently to raise the lid, and are tied with bow-knots over a roll of gauze or a piece of tubing.

All these steps should be taken with the usual antiseptic precautions. The sutures may be gradually tightened, until they have cut their way out. If suppuration occur they should be removed.

The effect is frequently temporary, because the strands of new connective tissue along the track of the sutures often relax and let the lid droop again.

There have been a number of interesting modifications of these methods of Dransart and Pagenstecher for uniting the lid to the frontalis by means of sutures. Some operators have used silk, some catgut, others platinum or gold wire.

Dehenne (*Bulletins et Mem. de la Soc. française d'Ophtal.*, Vol. IX, 1891, p. 83), advises the use of more resistant sutures than ordinary catgut, and therefore employs catgut sutures hardened in napthol, which he introduces after the manner of Dransart. He also makes use of platinum sutures.



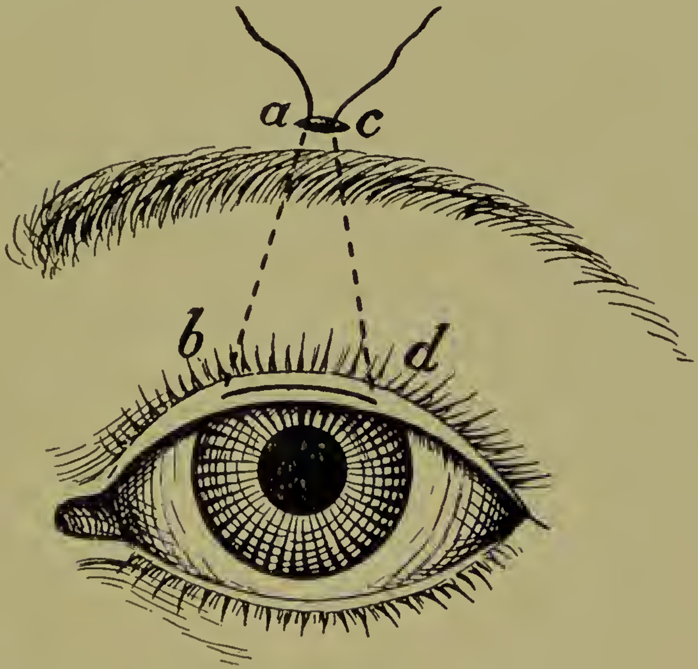
Pagenstecher's Operation for Ptosis.

The first needle enters the skin at *a* and passes subcutaneously to *b*. The second needle, on the same suture, enters at the same point, *a*, and passes beneath the skin to emerge at *c*; re-enters at *c*, and passes beneath the skin to *d*, in a course parallel to the first.

Gayet (*Bulletins et Mem. de la Soc. française d'Ophtal.*, Vol. IX, 1891, p. 83), uses platinum wires which he introduces after the manner of Dransart. When they are in place, before tying them, he attaches the ends of the loop to a battery capable of making them red-hot, and thus slightly cauterizes the track of the wires, to insure the development of cicatricial strands.

Birnbacher (*Archiv d'Ophtal.*, Vol. XII, p. 717), makes an incision through the skin of the lid corresponding to the superior border of the tarsus, which is exposed in nearly its whole length.

Three double-armed sutures of silk are passed through the superior border of the tarsus, 7 mm. apart. They are then passed subcutaneously, to emerge above the eyebrow, where each loop is held around a roll of gauze or a piece of tubing. They are left in place for at least three weeks. This operation, instead of being a new procedure, is almost identical with that of Dransart, with the slight difference that the sutures are tied above the brow, where they can be removed instead of being buried.

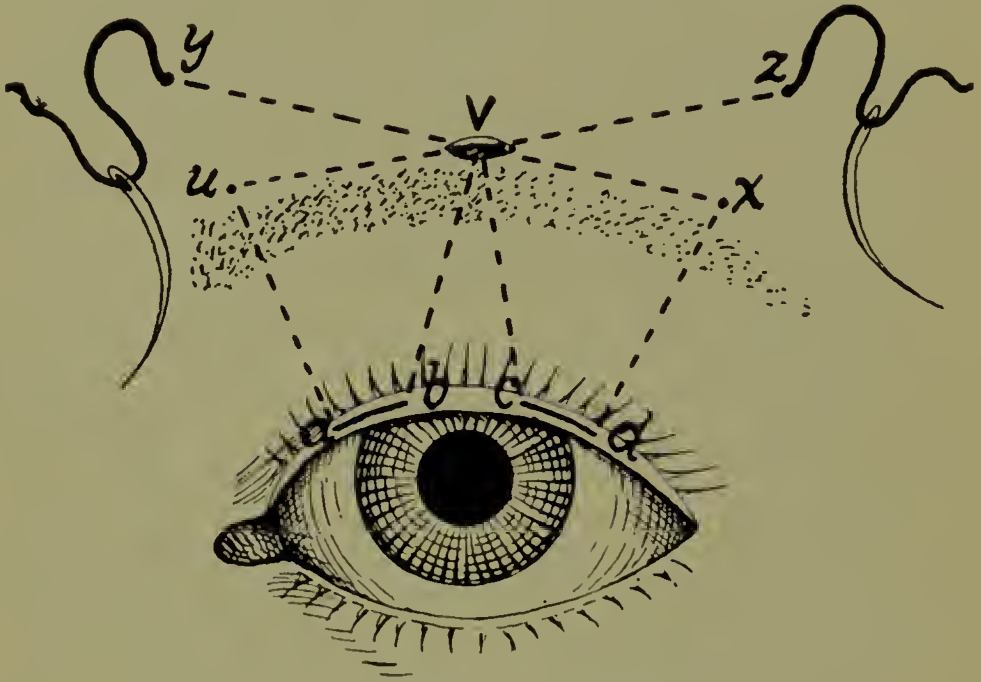


Mules' Operation for Ptosis.

a, c, a short incision, 3 mm. in length, above the eyebrow; *b, d,* incision 7 mm. in length, in the margin of the lid. An inserted gold wire emerges at *a, c,* and forms the loop, *b, d,* buried at the lid margin.

The following operation of Mules is in some respects similar to that of Pagenstecher.

Mules' operation for ptosis. An incision is made in the middle of the lid margin, about 6 or 7 mm. in length, just anterior to the row of openings of the Meibomian glands. This incision need not be more than 3 mm. in depth. A small incision, 3 or 4 mm. in length, is made a few millimeters above the eyebrow in a line vertical with the incision in the lid margin. A loop of gold is then passed in the following manner:—A special needle, with the eye near the end, is passed from the nasal end of the small incision above the eyebrow beneath the skin, to emerge at the inner end of the intermarginal incision b. The gold wire is threaded into the needle and drawn back with it so as to emerge at a. The needle is again passed through the other end of the superciliary incision, c, to come out at the temporal end of the intermarginal incision, d, where it is again threaded with the other end of the wire, which is drawn up beneath the skin of the lid. There is thus formed a loop of wire which sinks into the margin of the lid. The ends are then drawn up slightly more than is necessary to produce the desired elevation of the lid, and are twisted over a probe, which is laid across the small skin incision above the brow. The ends are then cut short and the probe withdrawn, when the loop sinks into the little wound, which may then be closed, if necessary, with a suture. There is thus produced a loop that acts as a permanent tendon.



Worth's Operation for Ptosis.

a, *b*, and *c*, *d*, are intermarginal incisions in the gray line, 4 mm. in length, 2 mm. in depth; *v*, a small puncture-incision above the shaved brow. The first needle passes from *b* to *v*, is reinserted at *v*, and emerges at *c*; then inserted at *d*, to emerge at *x*, and, finally, at *y*. The other needle passes from *a* to *u*, and finally crosses to *z*. Traction on the sutures at *u* and *x*, elevates the lid to the required extent, and the sutures are fixed by passing them on to *y* and *z*.

The advantages urged for this method are its simplicity, the absence of scar and the short time of convalescence. The contention that the metallic foreign substance is liable to be extruded because of the motion of the lids is met by the statement of Grimsdale and Brewerton (*A Textbook of Ophthalmic Operations*, p. 64), that they have not known this to take place when the wire is properly introduced and firmly enough twisted, with the ends sufficiently buried in the little wound.

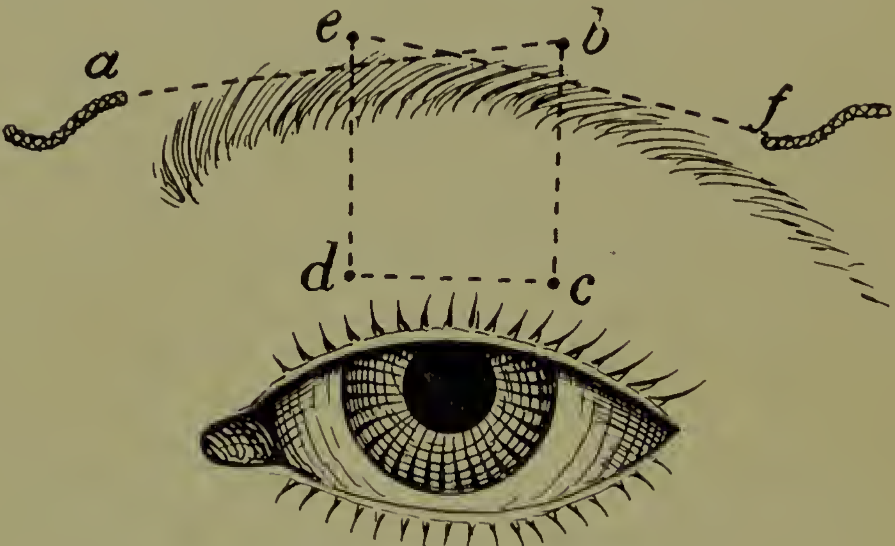
Worth's operation. Worth (*The Ophthalmoscope,* Vol. I, p. 13), modifies the operation of Mules by using kangaroo tendon specially prepared by splitting and scraping it (to make it smooth), then soaking it in ether (to remove the grease) and, finally, in a solution of biniodid of mercury. It is lubricated with sterilized vaseline. In passing it subcutaneously it takes a long course to avoid making a knot in the suture.

The eyebrow is shaved. Two small incisions, about 4 mm. in length, are made in the gray line of the lid, about 3 mm. on either side of the middle of the lid margin, a, b, and c, d, as shown in the figure. The suture is threaded on two firm Hagedorn needles. The first needle enters the end of the intermarginal incision, b, and passes subcutaneously to the little incision above the brow at v. It is re-introduced here and passes beneath the skin of the lid, to emerge at the inner end of the other intermarginal incision at C. This makes a loop, b, v, c.

The first needle now enters the outer end of the marginal incision, d, and passes subcutaneously to x, while the needle on the other end of the suture enters at the outer end of the other marginal incision at a, and emerges at u, the course of these diverging slightly. By slight traction on the loops at a, b, and c, d, the point of attachment at v is sunk into the tissues, and then by traction on the suture at u and x the loops are drawn into the intermarginal incisions and the lid is raised to the extent desired. Finally, the needles are re-introduced at their points of emergence, u, and x, and are passed subcutaneously across the eyebrow, emerging at y and z respectively, where they are cut short that they may retract beneath the skin. No scar is left and the results obtained by the method are said to be good.

Harman's operation. Harman (*The Ophthalmoscope,* Vol. 1, p. 137), instead of the kangaroo tendon, which is difficult to prepare, used a delicate gold chain of the kind known as "wove chain," strong enough to sustain a weight of 15 pounds. A bayonet-shaped, 4-inch, abdominal needle was used, and either soldered to the chain or attached to it with a silk thread. It was passed in the following manner, indicated in the diagram.

The needle is inserted into the skin at a point near and above the nasal end of the eyebrow, a. It then passes beneath the skin and muscle to b, external to the middle of the brow, where it emerges. About 6 inches of the chain is drawn through—enough to complete the suture. The needle is reintroduced at the pont of emergence, b, and follows a vertical path beneath the skin to a point, c, a few millimeters above the lid margin, where it is again brought out, and the chain drawn through. It is reinserted at this point of exit, and passed to the point, d, in a course parallel to the lid border; the needle in this course passing through the tarsus. From the point, d, the chain passes upward in a course parallel to b, c, to emerge at e, above the eyebrow, where it is passed to f, a point above the temporal end of the eyebrow. Traction on the chain elevates the lid to the required degree, and the ends of the chain are then cut off and left buried in the tissues. Granulation tissue develops in the meshes of the chain and it becomes encapsulated. Grimsdale and Brewerton state (*A Textbook of Ophthalmic Operations,* p. 68), that this method is but little more difficult than the Mules' because the marginal incision is avoided. They point out the necessity for particular attention to antiseptic details, to prevent infection of the lid tissues by the chain.

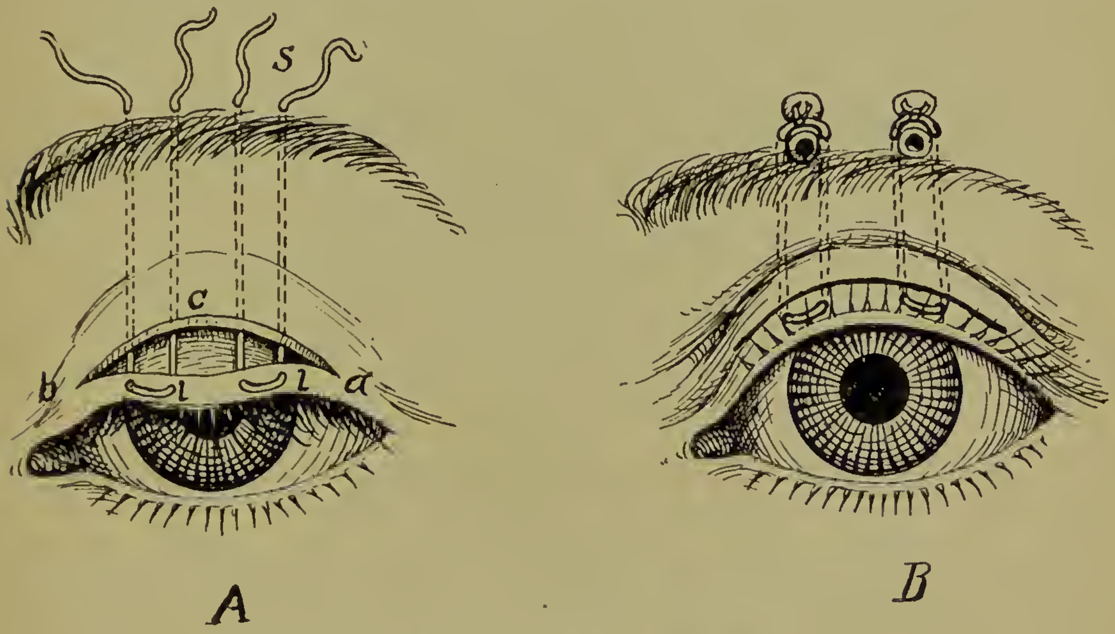


Harman's Operation for Ptosis.

"Wove chain" suture is passed subcutaneously from *a* to *b*. The needle is re-inserted at *b*, passes to c, then to *d*, and *e*, and finally emerges at *f*. In its course from *c* to *d*, it passes through the anterior part of the tarsus. (After Grimsdale and Brewerton.)

de Wecker's operation. de Wecker (*Annales d'Oculist.,* 1882, Vol. LXXXIII, p. 29), combined the principles of the Graefe and Pagenstecher operations in the following manner: An oval piece of skin with the bundle of orbicular fibers corresponding to it is excised by making an incision 4 mm. or 5 mm. from the lid border along the length of the lid, a, b, and joining this at each end with a curved incision, c, parallel to the superior border of the tarsus. (See the illustrations.)

Two loop sutures are then passed at a suitable distance apart, from the lower skin flap of the eyelid to points above the eyebrow. Double armed sutures are then employed in the following manner: One needle of the suture is inserted through the skin of the lower flap, to emerge in the wound; it is then reinserted beneath the skin of the upper lip of the wound, to emerge above the eyebrow. The other needle, following a parallel course after being introduced about 4 mm. or 5 mm. from the first, in the lower skin flap, leaves a loop on the skin above the lid border. (In this respect it differs from the Pagenstecher suture, the loop of which is buried.) After making the necessary traction to elevate the lid, the sutures are tied over a roll of gauze or tubing.



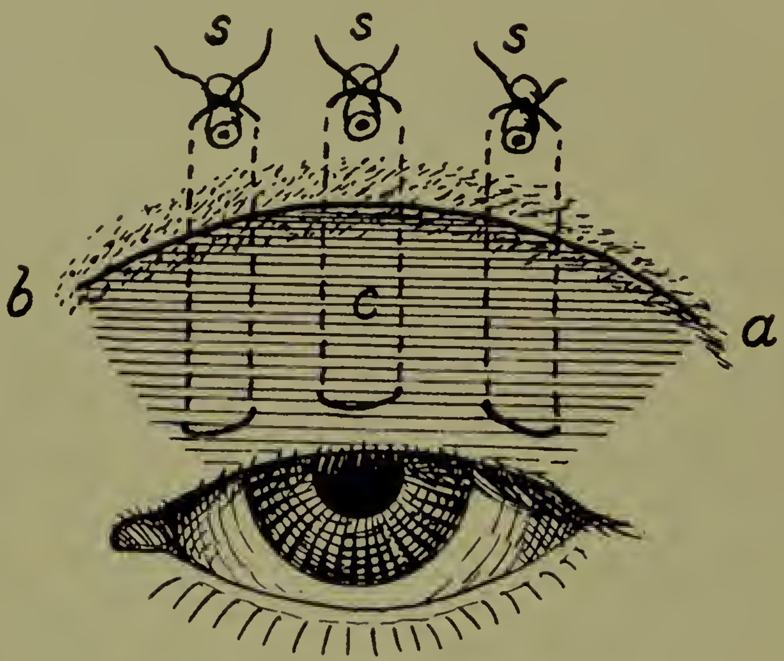
de Wecker's Operation for Ptosis.

The incision, *a*, *b*, parallel to lid border and 4 mm. above it, is joined by the curved incision, *a*, *c*, *b*. An oval piece of skin and the corresponding muscle are excised. Double-armed sutures pass through the lower skin flap, forming loops, *l*; then across the wound to enter the subcutaneous tissue of the upper flap, and emerge above the eyebrow. Traction on the sutures elevates the lid and closes the wound.

As in other operations of this variety, the sutures may be first tied with a temporary bow-knot, so that the tension on the lid may be increased or diminished after a few days, as required, when the sutures can be more securely tied.

Such an operation is applicable to those cases in which there is considerable redundancy of the lid skin.

Operation of Hess. After shaving the eyebrow, an incision is made along its whole length through the skin only. (See the figure.) The lower skin flap is then separated from the muscle layer by dissection, nearly to the lid border. After this is accomplished the surgeon can estimate the amount of elevation to be produced and the points where sutures should be placed by seizing the skin flap from the inner side with forceps and noting the effect. Three double-armed loop sutures are then introduced, so that the loop will be on the skin surface at places determined by traction with the forceps mentioned. (*Archiv f. Augenheilk.*, 1893, Vol. XXVIII, p. 22.) The sutures are then passed beneath the brow, to emerge 1 cm. or more above it, where they are tied around rolls or tubing. The skin wound is closed with sutures. The main sutures are allowed to remain for two weeks. Traction on the sutures raises the lid, and the skin is folded on itself in the position of the normal sulcus. The scar is concealed when the hair of the eyebrow grows again.



Hess Operation for Ptosis.

An incision, *a*, *b*, is made along the line of the previously shaved brow. A skin flap, *c*, is then dissected away from the muscle fibers nearly to the lid border, as indicated by the shading. Loop sutures are then placed in the manner indicated, the loops being on the skin surface.

Landolt's operation. Landolt (*Archives d'Ophtal.*, 1897, Vol. XVII, p. 1) modifies the procedure of de Wecker in the following manner: After the incision is made, 4 mm. above the free border of the lid and parallel to it, the superior flap of skin is separated to the level of the orbital margin, without excising any of the skin. Three loop sutures, double armed, are then passed through the lower lip of the wound, the needles on each suture entering about 6 mm. apart, and taking hold of the tarsus. They are then passed beneath the separated skin flap, to emerge above the eyebrow, where, after sufficiently elevating the lid by traction, they are tied with a bow-knot over a piece of tubing or gauze. By traction on the sutures, the border of the lid is drawn up under the superior lip of the incision. Immediately after the operation the raw edge forms the border of the lid; but, according to Landolt, this edge usually retracts to its proper position. Should it fail to do so after some days, when cicatrization of the deeper layer is sufficiently advanced to show the effect produced on the ptosis, a similar row of loop sutures is passed through this skin flap, these sutures also emerging above the eyebrow. Landolt prefers treating this overhanging skin flap by a subsequent operation, because, if the effect of the first be insufficient, it may be increased by the second row of sutures; if the effect of the first operation be too great, it is diminished by loosening some of the cicatricial bands at the same time that the second sutures close the skin wound.

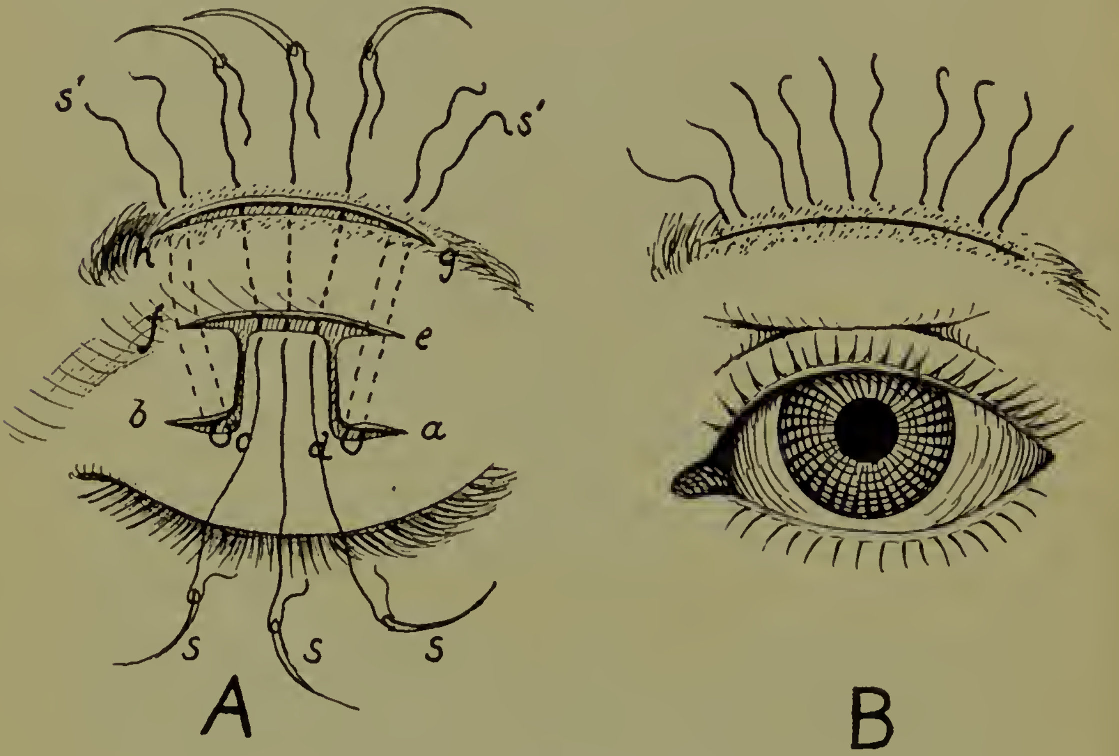
CLASS II, GROUP B. SUBSTITUTING THE ACTION OF THE FRONTALIS MUSCLE FOR THAT OF THE LEVATOR BY MEANS OF FLAPS OF SKIN.

Operations of this class are especially applicable to cases of partial or complete ptosis, in which it can be demonstrated that the levator muscle possesses very little or no power to raise the lid, either from a paralysis that has resisted treatment or from imperfect development or absence of the muscle.

Operation of Panas. In this well-known operation (*Archiv. d'Ophtal.*, 1887, Vol. VI, p. 1), a flap of skin from the anterior surface of the eyelid is attached to the frontalis muscle. (See Fig.)

The eyebrow is shaved. The lid is drawn down over a Jaeger plate, and a horizontal incision, a, b, is made from nearly one commissure to the other, interrupted in the middle, for 8 mm. or 10 mm., at c, d. This incision follows the fold of separation of the tarsal and orbital portions of the lid. From the inner ends, c, d, of the interrupted incision, two vertical, parallel incisions are made that extend to the fold between the lid and the eyebrow. A horizontal incision, e, f, joining these two and extending 1 or 2 mm. on either side of them, is then made. This incision passes through the skin and muscle to the tarso-orbital fascia. The nearly rectangular flap is then dissected up, by separating it from the tarsus, so that it contains fibers of the orbicularis.

A third incision, g, h, parallel to the preceding, is then made through the skin and deep tissue of the eyebrow, and the bridge of tissue, e, f, g, h, thus marked out, is undermined. The distance one must place the incision, g, h, from f, e, will depend upon the degree of elevation of the lid when one draws the flap upward; hence the degree of elevation is practically equal to the width of the bridge. Three sutures pass through the upper edge of the rectangular flap, then beneath the bridge to the upper lip of the incision in the eyebrow. These sutures can be more readily passed beneath the bridge and the flap drawn up into place if the bridge is drawn forward with a strabismus hook.

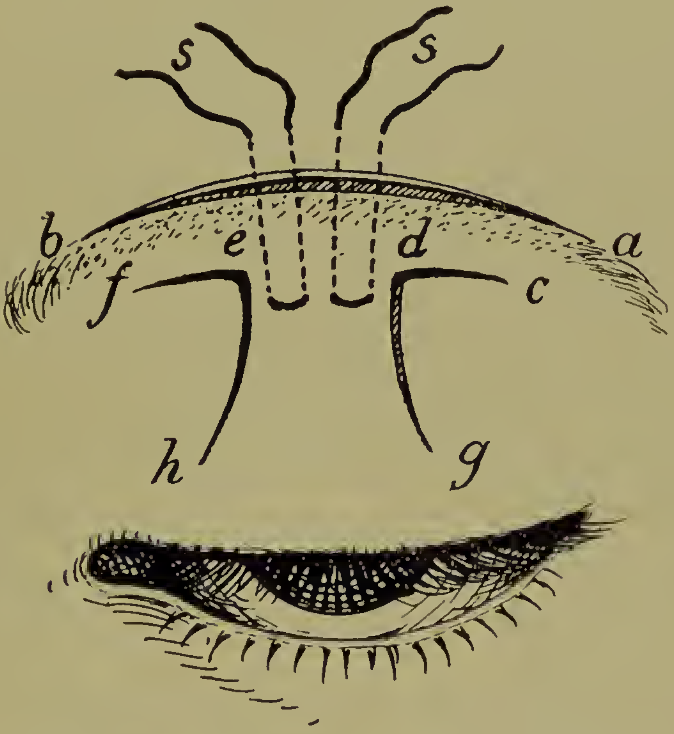


Panas' Operation for Ptosis.

Incision *a, b*, are made parallel to the lid border and about on a level with the superior border of the tarsus. The line of this incision is interrupted at *c, d*. From these points two vertical incisions are made up to the fold between lid and eyebrow. These are joined by an incision, *e, f*, and the rectangular flap is loosened. *g, h*, shows the incision in the brow. The bridge, *e, f, g, h*, is undermined, and beneath it the rectangular flap is fixed by sutures. *s, s*, are loop sutures taking hold of the tarso-orbital fascia and emerging above the brow. *b*, completed operation.

When the flap is in position there may be a tendency to slight ectropion. To obviate this, before drawing the flap beneath the bridge, Panas placed two lateral loop sutures, s, s, which take hold of the edge of the tarsus and the fascia where it is exposed behind the points, c, d, and emerge above the brow. Traction on these tends to draw the tarsus straight up. They may be tied over rolls of gauze.

This operation is applicable for cases of complete ptosis in which there is absolutely no power of the levator. It will unquestionably raise the lid, but has the distinct disadvantage that it places the skin surface of the flap in apposition with the raw under surface of the bridge. Healing of this under surface must be by granulation, hence the recovery is considerably delayed. Furthermore, the little pocket thus formed gathers dirt and epithelial scales and is not easy to keep clean.



Grimsdale's Modification of Panas' Operation.

a, b, incision above the eyebrow.

c, d, e, f, short incisions, 4 mm. or 5 mm. below *a, b.*

d, g, and *e, h,* vertical incisions extending downward to the upper border of the tarsus and diverging slightly below.

The tissue thus outlined is undermined, so that it will slide upward and elevate the lid by traction on the sutures.

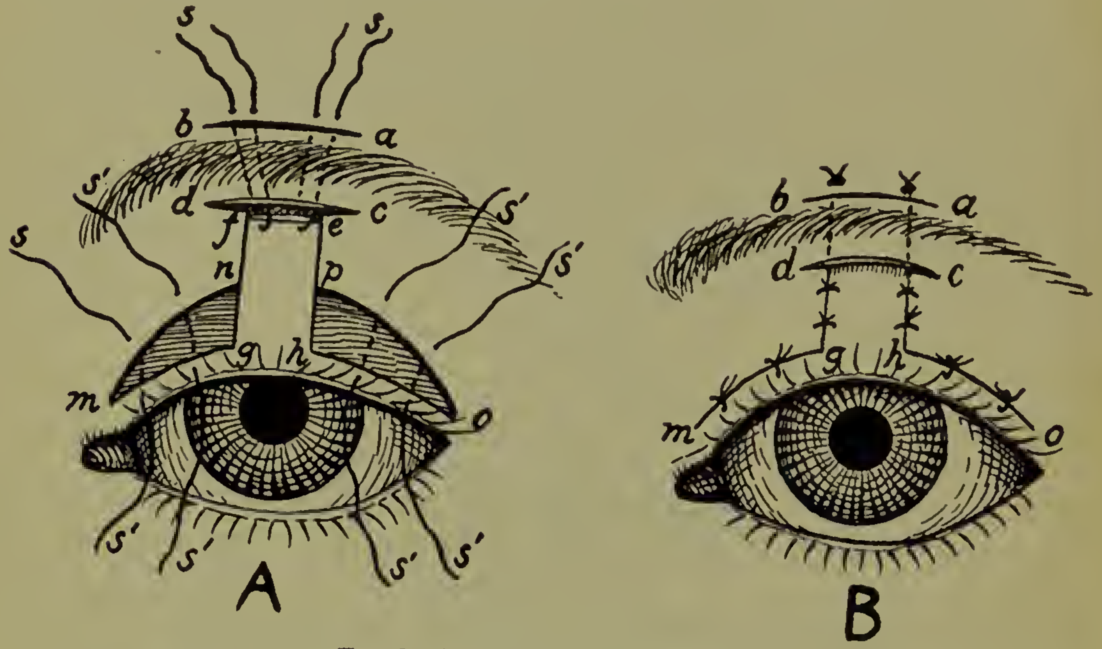
For these reasons, several modifications of this method have been suggested that are real improvements and make it a desirable operation of its class.

Allport's modification of Panas' operation, see p. 246, Vol. 1, of this *Encyclopedia.*

Grimsdale's modification of Panas' operation. Grimsdale (*A Text-book of Ophthalmic Operations,* 1907, p. 72), offers his modification to avoid the objectionable coaptation of skin to a granulating surface, which is the chief disadvantage of the Panas operation.

The first incision is made in the usual way above the brow. (Fig. a, b.)

If the amount of elevation desired is about 6 mm. the surgeon makes two shorter incisions, c, d, and e, f, about 3 mm. below the first and separated by a space of 10 mm. From the inner ends of these, two vertical incisions, d, g, and e, h, are carried downwards for about 12 mm., and then turned slightly towards the inner and outer extremities of the lid. The whole area marked out by these incisions is then undermined so that it will move readily.



Tansley's Operation for Ptosis.

a, b, incision above the brow, 12 mm. long.
c, d, incision below the brow, 12 mm. long.
e, h, f, g, tongue flap of skin dissected back and left attached at *g, h.*
m, g, h, o, incision, 3 mm. from the border of the lid, joined by *n, m,* and *p, o,* that follows the line of the superior border of the tarsus.
s, s, sutures in the end of the tongue flap draw it under the bridge, to attach it to the lip of the incision, *a, b.*
s, s, sutures closing the wound in the lid.
B, appearance after closing the wound.

Two stout, double-armed sutures are passed through the skin between the vertical incisions, at a distance of 6 mm. from the first incision, and then upward, under the loosened skin to the first incision; here they sink deeply through the frontalis to emerge above the brow. When tightened, the loose fold of skin between the vertical incisions is drawn up under the eyebrow, to be attached to the frontalis. The sutures are then tied over rolls.

Tansley's operation. (*Trans. Amer. Ophth. Soc.*, 1895, Vol. VII, Pt. II, p. 427.) This is a combination of the principles of Hunt and

Graefe with that of Panas, as shown in the accompanying figures.

Two vertical, parallel incisions, about 6 mm. apart, are made in the center of the lid, extending from the orbital margin below the eyebrow to points about 4 mm. above the free border of the eyelid. At their upper ends these incisions are united by a horizontal one, c, d, and the tongue flap, e, f, g, h, is separated by dissection with knife and scissors, leaving it attached at g, h. This narrow flap is then wrapped in a piece of gauze wet with warm salt solution, and the incisions, h, o, and g, m, are made from the base of the flap, parallel to and about 4 mm. from the free border of the lid, extending a trifle beyond the internal and external canthi. Joining these at each end are two curved incisions, p, o, and n, m, that follow the crease showing the upper limit of the tarsus. The skin and muscle fibers between these incisions are then excised, leaving the tarsus denuded of tissue.

A short incision, a, b, 8 or 10 mm. long, is then made above the eyebrow, parallel to and directly over the one below the brow, c, d, and the tissue is undermined with a Graefe knife, to allow the passage of the end of the tongue flap.

A strong suture in the end of this flap is used to draw it up beneath the brow, and when it is sufficiently tight to produce the required elevation of the lid any excess is cut off even with the forehead. The little flap is then united to the upper skin incision with two fine sutures. Superficial sutures close the denuded area and unite the sides of the tongue flap to the lips of the vertical wounds.

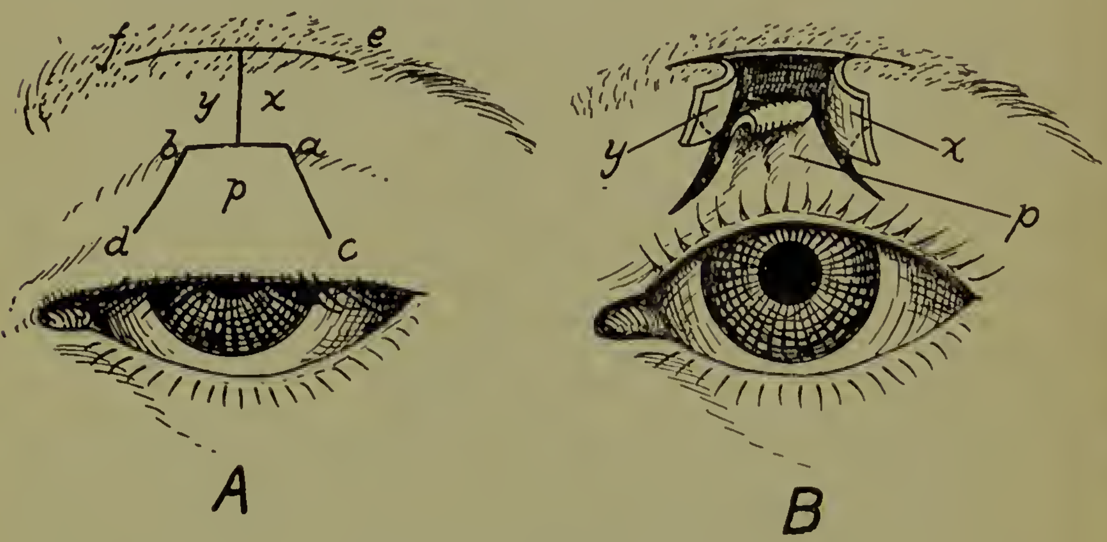
The sutures are removed from day to day, as seems advisable.

Here, again, there is the disadvantage of a cutaneous surface being apposed to a granulating one, but the operation is said to give excellent results in cases of complete ptosis.

Rollet's operation. Rollet (*Révue gén. d'Ophtal.,* Feb. 28, 1910, p. 49), endeavors to overcome the objection of having a raw surface in contact with a cutaneous one by a modification of the Panas principle, in which the skin flap is more accurately attached to the frontal muscle.

The eyebrow is shaved. A horizontal incision is then made in the orbito-palpebral fold about 12 mm. in length, according to the subject. (See Fig. a, b.) From this incision two diverging incisions pass downwards toward the border of the lid. The flap thus marked out, a, b, c, d, is separated by dissection from the underlying parts, and contains skin and orbicular muscle fibers. A horizontal incision is then made in the eyebrow, about 2 cm. in length, extending to the bone, e, f, and from the middle of this a vertical incision is made between two horizontal incisions. The upper part of this vertical incision is as deep (reaching the bone) as the superior one, while the lower part is superficial where it joins the lower incision.

The two lateral flaps, x, y, are then dissected back and the corners trimmed off, to avoid too great puckering. The palpebral flap is then drawn up to the required extent, and it, too, is trimmed to a somewhat pointed form with scissors, to make the lateral flaps fit it. It is then held in place by two layers of sutures, the deeper ones, of catgut, uniting the orbicularis muscle fibers in the flap with the fibers of the frontalis; that can be seen in the upper lip of the incision, and the lateral flaps, x and y. Finally, cutaneous sutures of silk close the wounds, by uniting the edges of the lateral flaps with the edges of the tongue flap.



Rollet's Operation for Ptosis.

a, b, incision, about 12 mm. in length, just beneath the brow.

a, c, b, d, diverging incisions down to 4 mm. above the edge of the lid, marking out flap, *p.*

e, f, incision in the eyebrow, that has been previously shaved. A vertical incision joins these at middle points.

x, y, lateral flaps that are dissected back, giving place for accurate disposition of the flap *p,* which is slightly trimmed and united to the muscle layers by deep, catgut sutures. Superficial sutures unite the lateral flaps with the edges of the tongue flaps.

Operation of Darier. Darier (*Soc. d'Ophtal. de Paris,* 1897, p. 110), endeavored to secure the tissues of the lid to the frontalis muscle by attaching small strips of orbicularis muscle to it. This he did by excising a narrow oval strip of skin from the eyelid. He then, by dissection, prepared two small tongues of muscle fibers from the exposed orbicularis, 3 mm. wide and 15 mm. long. He then made two narrow tunnels beneath the eyebrow, emerging above it, and into these the narrow tongue flaps of muscle were passed and secured with sutures.

CLASS II, GROUP C. SUBSTITUTION OF THE ACTION OF THE FRONTALIS FOR THAT OF THE LEVATOR PALPEBRÆ BY ATTACHING A FLAP OF THE FORMER MUSCLE TO THE LID.

Operation of Fergus. Fergus (*Brit. Med. Jour.*, March 30, 1901) recommends preparing a tongue flap of frontalis muscle fibers and suturing it to the anterior face of the tarsus. An incision is made, the length of the eyebrow, extending upward at its temporal end. The upper lid of the wound is dissected upward for 2 or 3 cm., exposing the frontalis muscle. The lower flap of the wound is dissected downward, the orbicularis being included nearly to the free border of the lid, exposing the tarsus. With the upper lid strongly retracted, the surgeon prepares a tongue-shaped flap of the frontalis muscle opposite the center of the lid, nearly 2 cm. broad and 3 or 4 cm. long, which is then separated from its attachment at its lower end. Two double-armed loop sutures are passed through the free end of the flap of muscle from without inward, and then the needles take a firm hold of the tarsal plate, and finally emerge from the skin near the free margin of the lid. The sutures are tied over a small piece of tubing, and the wound in the brow is closed by ordinary sutures.

CLASS II, GROUP D. ATTACHING THE TENDON OF THE LEVATOR PALPEBRÆ TO THE FRONTALIS.

This method is practised to give the frontalis a direct attachment to the lid, but instead of drawing the lid upward and backward as the levator does, it cannot do better than draw it straight upward, as do all the operations in Class II.

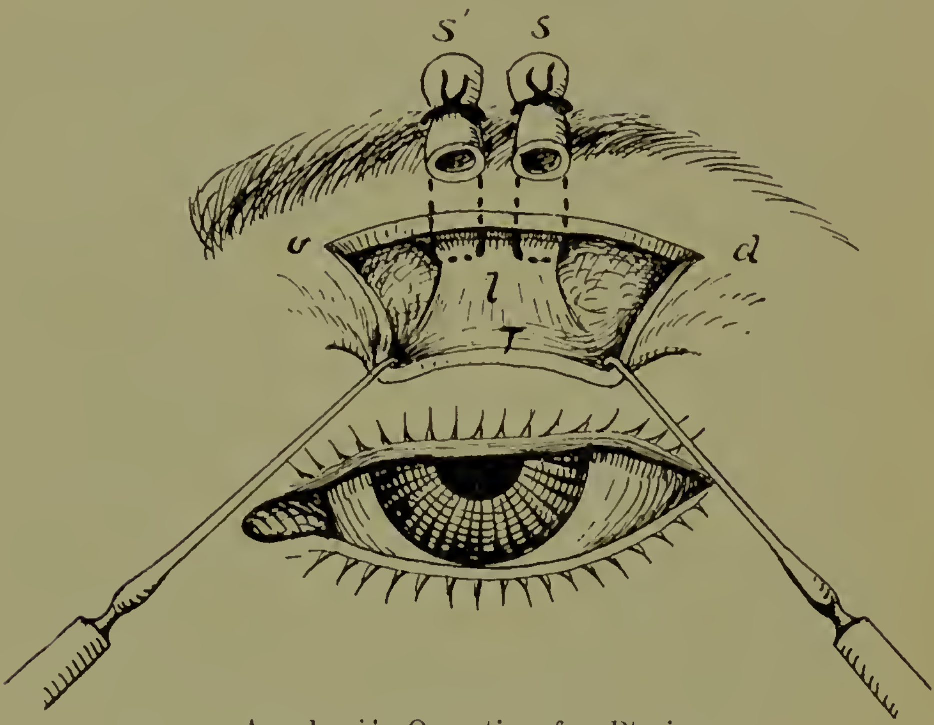
Operation of Angelucci. (*Compt. rend. XIII. Congrés internat. de Médicine,* Paris, 1900, p. 329). An incision is made 3 or 4 mm. beneath the line of the eyebrow, and parallel to it, about 2½ cm. in length (see Figure a, b). The lower flap is dissected down to the level of the tarsus and held back by retractors. Two or three mm. above the superior border of the tarsus a horizontal incision is made through the fibers of the orbicularis, to lay bare the tendon of the levator.

The tendon is then raised on a strabismus hook and divided 4 mm. above its attachment to the superior border of the tarsus. The tendon is then transfixed by two double-armed loop sutures, the needles passing from before backward, and the loops are tied on the posterior surface of the tendon, to prevent the threads from pulling out.

The tissues beneath the eyebrow are then separated from the periosteum and the needles are passed beneath, to emerge on the skin, 2 to 5 mm. above the brow. The sutures are then drawn sufficiently to uncover the pupil, and tied with bow-knots over a piece of gauze or tubing. Skin sutures are almost unnecessary. At the end of twenty-four hours the sutures may be tightened or loosened, as the case requires.

This operation is not applicable to cases in which the tendon of the levator is much atrophied, or is altogether absent.

Operation of Sourdille. Sourdille (*La Clinique Ophtalmol.*, 1903, p. 73) modifies this procedure so as to preserve the orbitopalpebral fold. He makes a curved incision 2½ cm. in length (as shown in the figure) and so placed that the summit of the curve will be about the superior border of the eyebrow; the extremities 2 mm. beneath the inferior border. The incision extends through skin, connective tissue and muscle down to the periosteum. By dissecting the lower flap downward he lays bare the upper part of the septum orbitale. This is divided near the orbital margin for a length of 1½ or 2 cm. The orbital fat that presents is pushed aside and the levator palpebræ seized on a strabismus hook, and two sutures are passed through

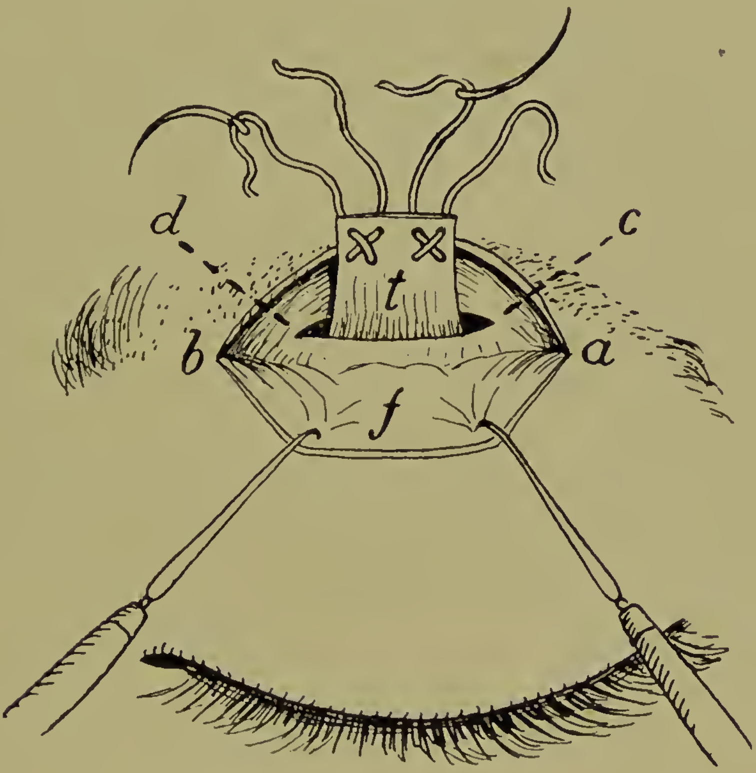


Angelucci's Operation for Ptosis.

a, b, line of incision, 4 mm. below the brow, 2½ cm. long.
t, superior border of the tarsus.
l, tendon of the levator, which is divided and held up by loop-sutures, *s, s,* that emerge above the brow.

it. These are passed as follows: Each needle, on a double-armed suture, is passed through the tendon from behind forwards, the threads are then crossed and the needles transfix the tendon at a higher level, the suture thus making an X on the anterior surface of the tendon. When two such sutures have been passed, the tendon is divided.

A pocket is made under the eyebrow by separating the tissues from the periosteum with a scalpel, and the tendon is drawn up into this pocket by passing the needles attached to each suture through the frontalis muscle, to emerge on the skin 3 or 4 mm. from the superior border of the incision.



Operation of Sourdille for Ptosis.

a, b, curved incision in the skin, beginning 3 mm. below the line of the brow and extending to its upper edge.

f, lower flap dissected down and retracted.

c, d, incision in the tarso-orbital fascia, just beneath the orbital margin.

t, end of the divided tendon of the levator, through which are passed the sutures *en* X, preparatory to directing them into the pocket under the eyebrow.

Each suture is tied over a piece of gauze or tubing with a temporary knot, so that the suture may be tightened or loosened the next day, if necessary. Skin sutures close the wound, and the sutures may be removed at the end of the seventh or eighth day. Whether or not the tendon will act, pulley-like, around the margin of the orbit, as claimed by the author, is questionable; the probability is that the traction will be straight upwards, and in some cases with prominent brows upward and forward, so that there will be danger of throwing the lower border of the lid inward, thus causing entropion.

CLASS III. ADVANCEMENT OF THE POINT OF INSERTION OF THE LEVATOR PALPEBRÆ.

In considering the action of the upper lid, which rolls upward and backward like the visor of a helmet or the cover of a roll-top desk, the tarsus may be regarded as the continuation of the tendon of the levator palpebræ. Hence, for all practical purposes, the point of insertion of this muscle is advanced if a part of the tarsus is excised, or if a portion of the tendon is removed or folded on itself. All operations, therefore, that aim to shorten the skeleton of the lid by cutting out a piece of the tarsal plate, should be included in this class.

While operations of the preceding class are applicable to cases in which the levator is powerless, those now to be considered are suitable to those cases of partial ptosis in which the muscle retains a certain degree of power.

Sir William Bowman was probably the first to suggest and put into practice the principles of operation in this class, by excising a piece of the tendon, thus shortening it, and of shortening the lid by removing a portion of the tarsus. These original operations have been modified in various ways by Eversbusch, Grandmont and others.

CLASS III, GROUP A. PARTIAL EXCISION OF THE TARSUS AND LEVATOR TENDON.

Bowman's operation. (*Royal London Ophthalmic Hosp. Reports*, Vol. I, p. 34). The upper lid is strongly everted, and an incision is made through the conjunctiva along the length of the superior border of the tarsus. The conjunctiva is then dissected back with scissors and forceps so as to expose the tendon of the levator and the superior tarsal border. The tendon is then seized with toothed forceps, and two or three sutures are passed through it at points about 2 cm. back of its insertion. It is then cut off in front of the line of the sutures, and this piece, together with the superior border of the tarsus to which it is attached, is excised with the scissors. The needles on the sutures are then passed through the fresh border of the tarsus and the tendon attached to its new position.

CLASS III, GROUP B. ADVANCEMENT OF THE LEVATOR BY FOLDING THE TENDON.

The principle proposed by Bowman was followed by Eversbusch, who, instead of excising a piece of the tendon and tarsus, accomplished the same result by folding the tendon by means of loop sutures placed through it.

Operation of Eversbusch (*Klin. Monatsbl. f. Augenheilk.*, 1883, p. 100). General anesthesia is employed, and a Snellen clamp is placed as high up beneath the lid as possible. Before the clamp is set the lid should be drawn down between the blades and, in this position, fixed.

An incision the length of the lids is then made parallel to the lid border and half way between it and the eyebrow, through skin and muscle.

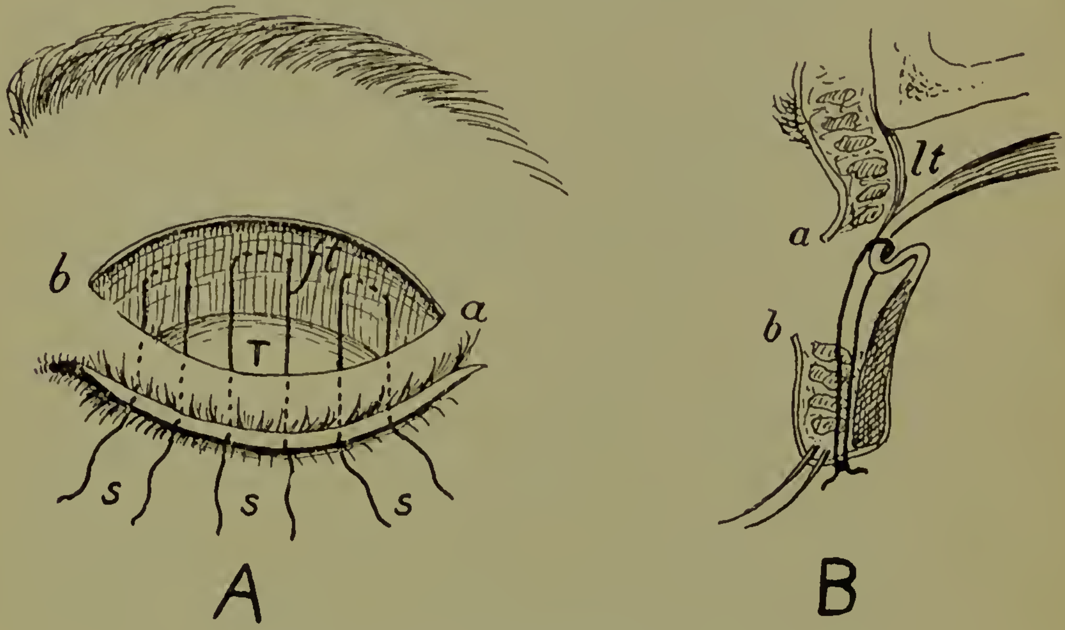
The upper and lower lips of the wound are then separated from the fascia and tarsus by loose dissection, so as to lay bare the tendon of the levator.

A suture of silk or fine catgut, doubly-armed with fine, curved needles, is then passed through the middle of the tendon, 3 or 4 mm. from the superior tarsal border. This is best done by seizing a vertical hold of the tendon with fine-toothed forceps, passing one needle through it (not including the conjunctiva) and bringing it out 2½ mm. from the point of entrance. The two needles then pass between the orbicularis muscle and the tarsus, to emerge on the gray line just behind the eyelashes, about 2½ mm. apart. A similar suture is passed about 3 mm. on each side of the central one. There are thus formed three loops on the posterior surface of the tendon. Before tying the sutures, the clamp is removed, and the musculo-cutaneous wound is closed with three sutures. The tendons are tied over beads, as in the Snellen entropion operation, to prevent them from cutting into the lid margin. Tightening the sutures folds the tendon forward on the anterior surface of the tarsus. In cases of redundancy of skin and muscle, Eversbusch recommends the excision of a strip of skin and muscle before closing the wound, after the manner of Graefe.

Both eyes are bandaged and the dressing is changed every day. The sutures are allowed to remain for several days, until there is sufficiently firm union between the folds of the tendon and the tarsus.

Snellen's operation. Snellen (*Trans. Ophthal. Soc. U. K.*, 1889, Vol. X, p. 207) suggested folding the tendon by the use of sutures alone, omitting the incisions. He passed a suture through the whole thickness of the lid just at the upper border of the tarsus. The lid was then everted, and the same needle was passed as high up in the fornix conjunctivæ as possible, through conjunctiva and underlying tendon and nearly to the skin of the lid. However, instead of piercing the skin, the needle was directed downward towards its original point of entrance, and emerged from the skin, about 2 mm. from this point.

Three such sutures are necessary, at equal distances apart, to correct the ptosis; and, because of the situation of the tendon of the levator, the middle one should be placed slightly nearer the internal angle of the lid than the external. The sutures thus placed form loops through the tendon and draw it forward. They are tied over beads or pieces of tubing.

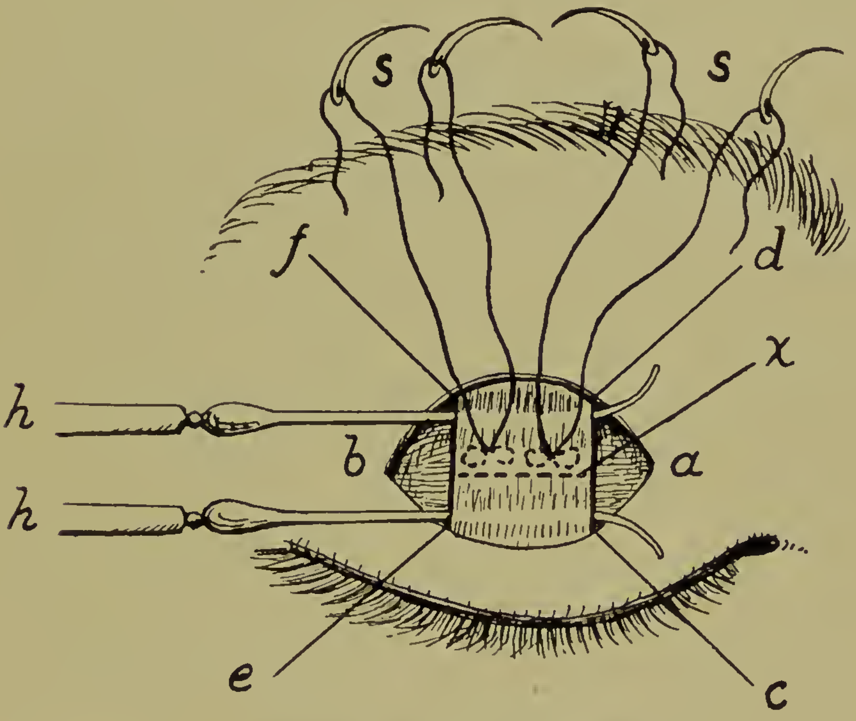


Operation of Eversbusch for Ptosis.

a, *b*, incision in the skin and muscle, exposing the tarsus, *t*, and *f*, *t*, the fascia, with the levator tendon.

s, loop sutures through the tendon, emerging at the border of the lid behind the lashes, fold the tendon forward, as indicated in the vertical section at *B*.

Wolff's operation. For cases of this class, Wolff proposes two forms of operation, one an advancement of the levator tendon after division of its tarsal insertion, made through a cutaneous incision; the other an advancement of Müller's muscle, done through a conjunctival incision. In the first operation a cutaneous incision is made 2 cm. in length, corresponding to the superior border of the tarsus. The skin is separated from the underlying muscle for 3 mm. above the incision and nearly to the free border below. About in the center of the convex tarsal border a fold of the muscle, with the underlying tendon, is seized with toothed forceps, and two vertical incisions, 1 cm. apart, are made with scissors through muscle and tendon. Beneath the bridge of muscle and tendon are then placed two strabismus hooks. (See figure.) Two double-armed catgut sutures are now passed through the tendon at a point high enough to allow resection of a piece of the tendon equal in length to the difference of width of the palpebral fissures. The sutures are tied, and the tendon divided immediately in front of them. The sutures are then passed through the stump of the tendon and the overlying orbicularis fibers at the superior border of the tarsus and tied. The skin wound is closed with three or four sutures which may be removed in four or five days.



Operation of Wolff for Ptosis.

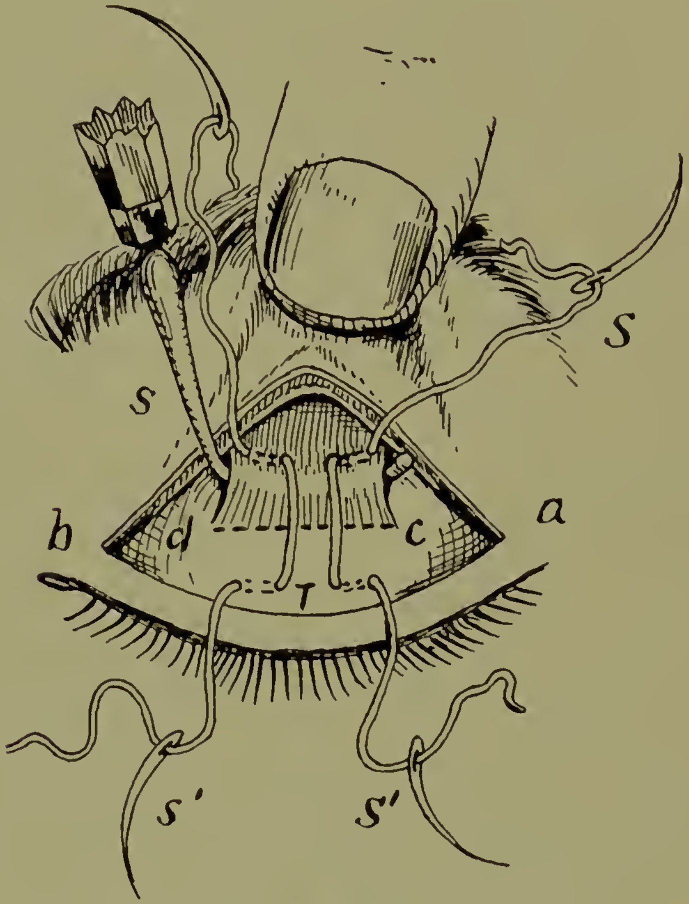
a, b, incision through the skin, 2 cm. long, exposing the orbicularis fibers over the superior border of tarsus.

c, d, and *e, f,* vertical incisions through the muscle and the levator tendon, to allow the tendon to be held up by hooks, *h. h.*

s, s, catgut sutures passed through the muscle and tendon, 6 mm. or 7 mm. above the line of insertion in the superior tarsal border. The tendon is then divided just below these, along the dotted line *x,* and the sutures attached to the superior tarsal border behind the remaining stump of the tendon.

By leaving the orbicularis intact, it is claimed that the union of the levator with the tarsus is made more secure, in that the tendon has an attachment, through the orbicularis, with the anterior face of the tarsus, in addition to that at the superior border.

In the other operation of Wolff, for shortening the muscle of Müller, the lid is held doubly everted, and a horizontal incision of 2 cm. is made in the fornix of the conjunctiva, exposing the muscle, which is then taken up on strabismus hooks. Catgut sutures are placed in the tendon as in the preceding operation, just back of the point where it is desired to resect the muscle. This point is determined by the difference in width of the palpebral fissures. After two sutures are placed in the tendon and tied, the tendon is cut off and the sutures are then passed through the superior border of the tarsus, tied and cut short. Five catgut sutures close the wound in the conjunctiva.



Lapersonne's Operation for Ptosis.

a, *b*, incision through skin and muscle, exposing the tarsus, *t*, and the tendon of the levator. Two vertical incisions at the side of tendon, from *c* and *d*, allow the tendon to be raised on the hook.

s, *s*, sutures forming a loop on the back of the tendon.

s' s' sutures passing through the tarsus.

c, *d*, line of division of the tendon at the tarsal border.

Both these operations are elaborate modifications of that of Bowman and are, in effect, a shortening of the levator tendon.

Operation of Lapersonne. Lapersonne (*Archiv. d'Ophtal.*, August, 1903, p. 497) has offered a modification of the Wolff operation, in which he makes a practical advancement of the point of insertion of the tendon of the levator, attaching it to the anterior surface of the tarsus, as shown in the figure.

A horn or metal plate is held beneath the lid, and an incision, *a, b,* is made through skin and muscle the length of the lid, about 4 mm. or 5 mm. above its free border. By light dissection the tarsus and the tarso-orbital fascia with the levator tendon are laid bare. Two small, vertical incisions, not involving the conjunctiva, are made on either side of the tendon, to permit the introduction of a strabismus hook with which to raise it. At a distance above the hook, depending upon the amount of elevation to be obtained, there is passed, through the lateral part of the tendon, one needle of a double-armed suture, which emerges 2 mm. from its point of entrance. A similar suture, is passed through the outer half of the tendon, thus making two loops behind it.

The attachment of the tendon to the tarsus is then divided at *c, d,* and, if deemed necessary, a piece of it may be resected.

The other needles on the sutures are then passed into the tarsus at a distance of 2 mm. or 3 mm. from the free for border, *s′, s′*. When the sutures are tied, the tendon is drawn down, to attach itself to the face of the tarsus. The skin wound closes naturally without the aid of sutures. The effect may be increased, however, by resecting a small strip of skin and muscle fibers, in which case the wound will be closed with fine sutures.

Elschnig's operation. The lid is held on a Jaeger lid-plate, and an incision is made down to the tarsus, 5 mm. above the lid border. The tissues are dissected back, above and below, to expose the tarsus and the tarso-orbital fascia. 10 mm. above the convex border of the tarsus, the fascia is seized in a thread loop, and then cut just below the loop from the median to the lateral angle. Retracting the fascia by means of the thread loop, the lower part of the fascia is carefully dissected away from the tendon and tarsus with scissors, nearly to the lid border.

The tendon of the levator, now in view, is seized with forceps, a loop suture is placed through it for control, and it is severed without cutting the conjunctiva. Holding it forward by means of the control suture, two or three fine, double-armed sutures are passed through it at such distances from the cut end as will insure the proper effect. The needles are then passed through the tarsal tissue, about 3 mm. from the lid border, and out through the skin.

Five catgut sutures then close the wound in the fascia; that in the skin is united with silk. After the skin wound has been closed, the tendon loops are tightened and draw the tendon down to its new attachment on the anterior face of the tarsus. They are then tied with bow-knots over pieces of tubing or gauze rolls; and the effect can be increased or diminished by tightening or loosening, at subsequent dressings. The superficial sutures are removed in three days; the deep sutures are allowed to remain from five to eight days.

It is difficult to understand the necessity for such a complicated dissection in order to attach the tendon to the anterior surface of the tarsus. The effect produced is the same as in the Lapersonne operation. Having the sutures emerge on the skin, to be tied over rolls, as in the Snellen procedure, seems to be an advantage.

CLASS III, GROUP C. ADVANCEMENT OF THE POINT OF INSERTION OF THE LEVATOR TENDON BY EXCISION OF A STRIP OF TARSUS.

As was previously stated, shortening the skeleton of the lid, the lid plate, by removal of a piece of it, is equivalent to resecting a piece of the tendon of the levator, so far as the action of that muscle on the lid is concerned. Whether or not one should remove a piece of the tarsus large enough to correct the deformity, is a question for careful consideration in any case.

Bowman (*Royal Lond. Ophthal. Hosp. Reports,* Vol. I, p. 34) seems to have been the first to conceive this idea and put it into practice, although the report of the case he published is rather incomplete. He made a skin incision parallel to and about 8 mm. above the lid border. Separating the wound, he excised an oval piece of subcutaneous tissues, including the tarsus and conjunctiva, and united the cut edges with sutures.

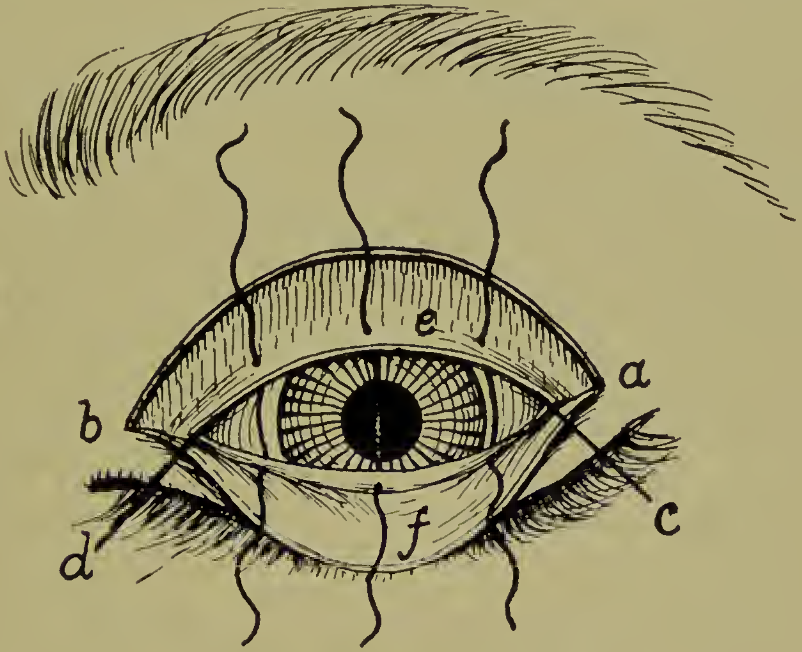
Operation of Gillet de Grandmont (*Bulletins et Mémoires de la Soc. franç. d'Ophtalm.,* Vol. IX, 1891, p. 80). The lid is held in a Snellen clamp, and an incision is made in the lid 2½ cm. in length, parallel to the free border and 3 or 4 mm. from it. (See figure.)

The wound is separated and the orbicularis fibers covering the tarsus are excised, leaving the latter bare in its whole extent.

An incision is then made through the tarsus and conjunctiva, parallel to the lid border, and 2 mm. or 3 mm. above it, this incision, *c, d,* being about 2 cm. in length. Joining this at each end is a curved incision, *c, e, d,* with its concavity downwards, passing through all the tissues to the blade of the lid clamp. The distance of the curved incision from the inferior one must be carefully determined by the degree of effect to be produced. At the widest part this distance should be equal to the difference in width of the palpebral fissures at the widest part, if one is normal.

The tissues bounded by these incisions are then removed. The edges of the deep wound thus made are united with fine catgut sutures. The skin wound will usually not require any.

Nicati (*Archives d'Ophtalm.,* 1890, Vol. X, p. 182) modified this procedure by excising the tarsus from the conjunctival side. The lid is everted, and each needle of a double-armed suture is passed through the conjunctiva at the superior border of the tarsus, and made to glide along the anterior surface of the tarsus and emerge on the free border of the lid, just behind the eyelashes. Three such loop sutures are passed at equal distances apart, after which a large portion of the tarsus is excised, preserving as much of the conjunctiva as possible. The sutures are then forcibly tied, and removed in three days.



Operation of de Grandmont for Ptosis.

a, b, incision through the skin and muscle, exposing the tarsus and the tarso-orbital fascia.

f, lower skin flap drawn downwards.

c, d, incision through the thickness of the tarsus, joined by the curved incision, *c, e, d,* near the upper margin of the tarsus; the tissue removed. The deep wound is closed by sutures.

Boucheron (*Archiv. d'Ophtal.*, 1893, Vol. XIII, p. 561) prefers an operation from the conjunctival side in cases of mild ptosis in women, to avoid the scar in the skin. Everting the lid, he first does a tarsectomy, reserving a band of tarsus above to which is attached the tendon of the levator, and one below, in which the lashes are placed.

Through this opening in the tarsus a part of the orbicularis muscle is removed, as this is antagonistic to the levator. Finally, the defect in the tarsus is closed by fine sutures.

Gruening (*Trans, Amer. Ophthal. Soc.*, Vol. IX, Pt. III, p. 574) operates according to the method of Grandmont, and thinks his method applicable to any form of ptosis requiring surgical intervention. The vertical width of the strip of excised tarsus should vary with the degree of the ptosis: it may measure as much as 7 mm., tapering at each end to 2 mm. He closes the tarsal wound by inserting three double-armed, loop sutures through the tarso-orbital fascia near the superior tarsal border, and bringing them out through the edge of the lid behind the eyelashes and tying them in the intermarginal space. He finds that patients operated on by this method are able to close the eyes well.

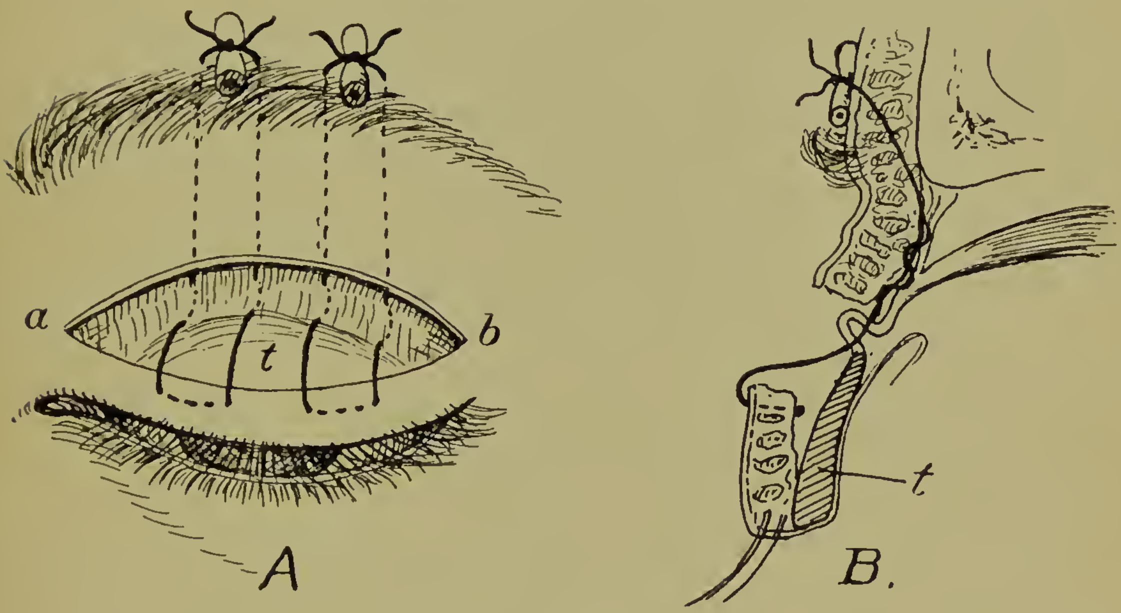
Theobald (*Trans. Amer. Ophthal. Soc.*, 1908, p. 673) excised the tarsus from the conjunctival side, making his first incision 3½ mm. from the free border of the lid, and a second one parallel to it and 3 mm. above. This strip of tarsus was removed and the wound closed by three fine, silk sutures. He did not excise any of the orbicularis muscle as did Boucheron. Placing knotted sutures on the conjunctival side of the tarsus, where they may come into contact with the cornea, is not to be recommended, as they may cause serious ulceration. If the excision is to be performed from the conjunctival side it would be better to follow the plan recommended in the Nicati operation for closing the tarsal wound.

Fergus (*Trans. Ophthal. Soc., U. K.*, 1908, Vol. XXVIII, p. 184), follows the principle of the de Grandmont operation in his most recent work, but modifies it to the extent of removing an oval piece of skin and muscle equal to the size of the tarsus that is excised. In removing the piece of tarsus he spares the conjunctiva. He uses catgut sutures to unite the wound in the tarsus, and superficial sutures to close the defect in the skin.

Mayou, after making a curved incision the length of the lid beneath the orbital margin, dissects back the skin and muscle so as to expose the tarsus and the tarso-orbital fascia. He then excises a strip 3 mm. broad from the whole length of the tarsal plate, without button-holing the conjunctiva. The cut margin of the tarsus is then attached to the levator palpebræ by two loop sutures of catgut, that pass through the tarsus below the wound, making a loop of about 3 mm., and then through the tarso-orbital fascia, tendon of the levator and orbicularis muscle in the upper part of the wound, where they are tied. The skin wound is closed with sutures. This would seem to be a combination of groups b and c—folding the tendon of the levator and excision of a part of the tarsus.

Some operators combine the principles of several groups that have been described. This is true of the procedure of Beard, in which the results are obtained by combining some of the features of the Hotz entropion operation with the principles of the Eversbusch operation of folding the levator tendon; also those of the Pagenstecher operation, of connecting the lid to the frontalis muscle by means of sutures.

Beard's operation (*Ophthalmic Surgery,* 1910, p. 241). After placing a horn plate beneath the lid, an incision is made just in the superior border of the tarsus, extending the whole length of the lid. (See Fig.) The divided fibers of the orbicularis are undermined above and below, exposing the tarsus and the tarso-orbital fascia. Two double-armed, No. 3, braided-silk sutures are passed in the following manner: Each needle on a suture is passed through the lower flap, near the edge from within outward, making the loop on its posterior surface.



Beard's Operation for Ptosis.

A. Front View.

a, b, incision at the superior border of the tarsus; *t,* tarsus. The sutures pass through the lower flap with the loop on its inner surface; they then gather the tarso-orbital fascia, and emerge above the brow.

B. Diagram of a vertical section of the lid, to show the course of the sutures.

The needles then pass in and out through the tendon of the levator and fascia, gathering it in folds, and finally emerge some distance above the eyebrow.

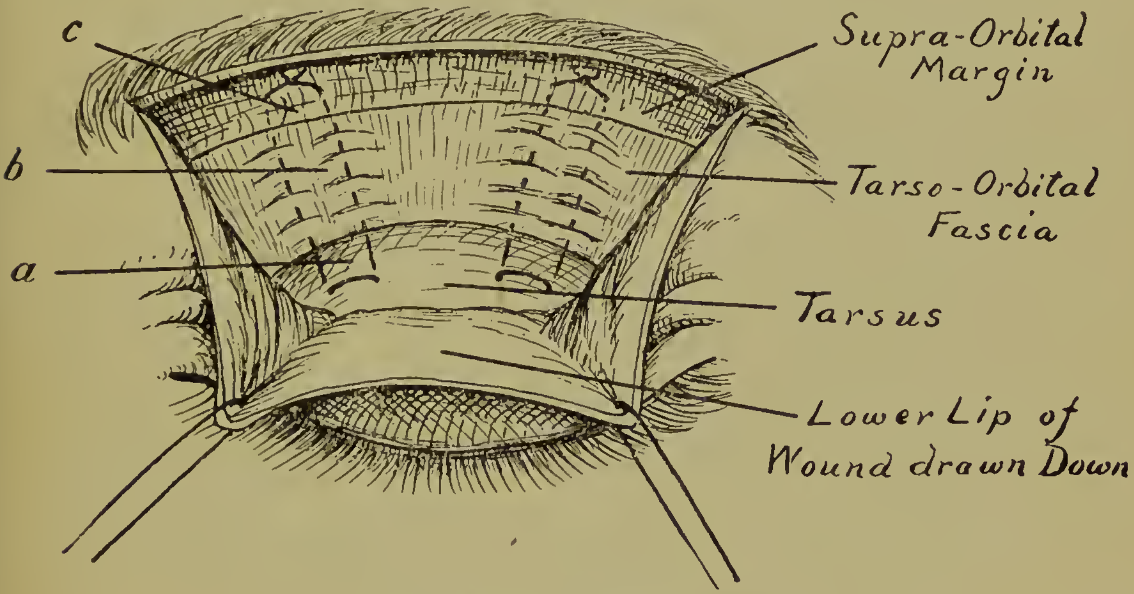
The sutures are so spaced that the loop, which is about 6 mm. long, is at the junction of the middle and end thirds of the tarsus. In tightening the sutures, the operator should, with toothed forceps, place the lower flap in proper position on the tarso-orbital fascia, and should also be sure that the edge of the upper flap is directed backward, that it may attach itself at the same point.

The sutures are then tied with bow-knots over gauze rolls, and can be tightened or loosened as desired when the dressing is changed after twenty-four hours. They are removed at the end of three or four days, when the parts have healed in their new position. The scar lies in the natural sulcus, above the tarsus.

Wilder's operation (*Trans. Amer. Ophth. Soc.,* 1897, p. 99). Some years ago the author proposed an operation for ptosis of folding upon itself the tarso-orbital fascia, as well as the aponeurosis of the levator which is intimately adherent to the fascia; and at the same time establishing a secure connection of the upper lid to the firm tissues of the eyebrow. It is a combination, therefore, of the principles contained in operations described in Class II, group a, with those described in Class III, group b.

The eyebrow is shaved, and an incision extending its whole length is made a little above the orbital margin, through all the tissues down to the periosteum. Retractors being used to draw down the lower lip of the wound, the skin and muscle are separated from the tarso-orbital fascia until the tarsus is brought into view. Sutures of fine, sterilized, hardened catgut, armed at each end with a curved needle are passed (see Fig.) in the following manner: The first needle is introduced deep enough into the tarsus to secure a firm hold at a point about at the junction of the outer and middle thirds, and a little distance below its convex edge. It is then drawn through, and with it several gathering stitches, b, are taken in the tarso-orbital fascia, after which the needle is passed through the muscle and connective tissue of the upper lip of the wound, c. The other needle on the same suture follows a parallel course in the same manner, enters the tarsus about 3 mm. from the point of entrance of the first, then, gathering the fascia into small folds and emerging in the tissue above, makes a loop by which the lid is drawn up. The second suture is passed in the same way, making a loop at the junction of the middle and inner thirds of the tarsus. The desired elevation of the lid may now be secured by drawing on the loops and tying the sutures, which are to be left in the wound.

In milder degrees of ptosis, in which some power remains in the levator, the sutures may be placed somewhat nearer together, to secure a hold on the central fibers of the levator tendon, and may emerge on the skin above the eyebrow to be tied over rolls, as in the Pagenstecher operation. In such cases the sutures may be of silk, to be withdrawn after seven or eight days when some degree of union has occurred between the folds in the fascia. However, in cases of complete ptosis, with no power in the levator, the buried sutures give additional strength to the folds of fascia, become encapsulated, and unite the lid to the frontalis, as well as shorten its suspensory ligament. The lower lip of the wound is united to the upper with fine sutures. The slight scar that remains after healing is almost entirely hidden when the eyebrow grows again. The orbicularis is uninjured, so that the patient retains to a certain extent the power of closing the lid. This operation differs from that of Dransart in that there is a shortening of the septum orbitale, really the suspensory ligament of the upper lid, together with a slight folding of the aponeurosis of the levator muscle. Added to these is the principle of attaching the frontalis to the lid by means of encapsulated sutures.



Wilder's Operation for Ptosis.

Incision along the supra-orbital margin, *c;* exposure of the tarso-orbital fascia and tarsus by separation of the lower flap. A suture passed into the tarsus at *a*, gathers the folds in the fascia, and is secured in firm tissue under the eyebrow.

CLASS IV. SUBSTITUTION OF THE ACTION OF THE SUPERIOR RECTUS FOR THAT OF THE LEVATOR PALPEBRÆ.

In this class of operations a new principle is introduced, of attaching the superior rectus muscle to the eyelid so that the lid will follow the upward movements of the eyeball. Furthermore, the movement of the lid after these operations is much more natural than when it is raised by the action of the frontalis muscle, which draws it straight upward, obliterating the natural folds and altering the expression of the face.

In considering the anatomical relation of these two muscles, it is to be remembered that they lie very close together, from their origin in the posterior angle of the orbit to their points of insertion, the levator palpebræ being directly above the superior rectus.

The layer of the deep fascia about the one merges into the fascia surrounding the other, and their tendinous expansions in front are separated only by the conjunctiva. They are innervated by the same nerve, the oculo-motor. In action, the structures to which they are attached describe the same upward curve; and they are so co-ordinated that one cannot turn the eye upward or downward without the lid following it.

Such considerations prompted Motais to devise the ingenious operation for ptosis that bears his name; and within two months from the time he read his paper on the subject at the annual meeting of the French Ophthalmological Society, in May, 1897, Parinaud presented to the Paris Ophthalmological Society an operation that he had devised, showing that he also had made use of the same principle, although the technic of his operation is quite different from that of Motais.

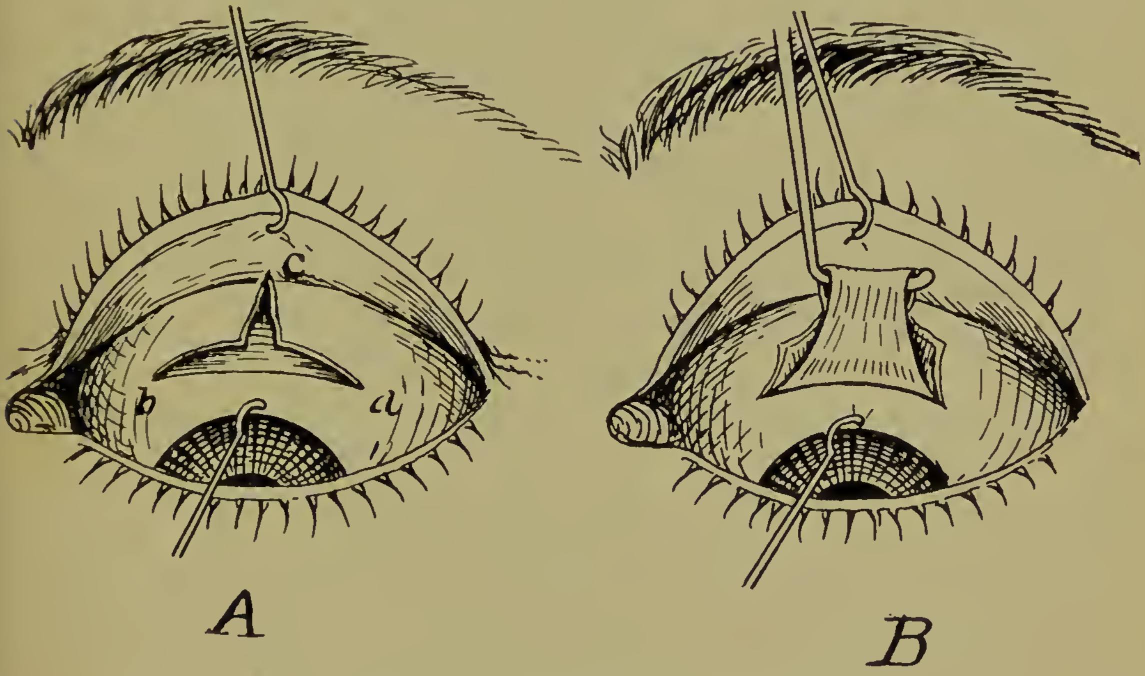
Naturally, these operations are not applicable to cases of paralytic ptosis in which all branches of the third nerve are involved, as is frequently the case. Neither would they be suitable for cases of congenital ptosis in which a weak upward movement of the eye indicates the possibility that the superior rectus, as well as the levator, is imperfectly developed; although cases have been reported in which there seemed to be an improvement of the working power of the superior rectus after raising the lid by the Motais operation.

Operation of Motais (*Soc. franç. d'Ophtal.*, 1897, p. 208). The operation may be done under cocain anesthesia. The upper lid is everted and drawn upward by an assistant, who places a sharp hook in the superior border of the tarsus. Another sharp hook is placed in the upper layer of the sclerotic coat, 4 or 5 mm. above the cornea, with which to draw the eye downward. (It might be safer to use a fixation forceps for this purpose.) A transverse, conjunctival incision, 10 to 12 mm. in length, is then made with scissors, 6 or 7 mm. above the cornea, and from the middle of this a vertical incision in the conjunctiva extending to the superior margin of the tarsus. (See fig. a, b, c.)

The conjunctival flaps are loosened and separated, so as to bring the tendon of the superior rectus into view, and beneath it a strabismus hook is placed as indicated in the figure.

The middle of the tendon is then seized with a pair of fine-toothed forceps, about 2 or 3 mm. from the line of insertion, and the middle fibers are cut for about 3 mm. at the line of insertion. From each extremity of this small, horizontal incision vertical ones are made in the tendon, 10 mm. in length, so that a tendinous flap is made in the middle of the tendon 10 mm. long and 3 mm. wide.

The end of this little flap is then held with a broad, conjunctival fixation forceps, to handle it more easily, and at about 3 mm. from its extremity two fine curved needles, on a double-armed suture, are passed through it ½ mm. from either edge. A pocket is then made on the anterior face of the tarsus, extending to within 5 mm. of the lid border, by cutting with scissors the tissues at the extremity of the vertical incision first made.

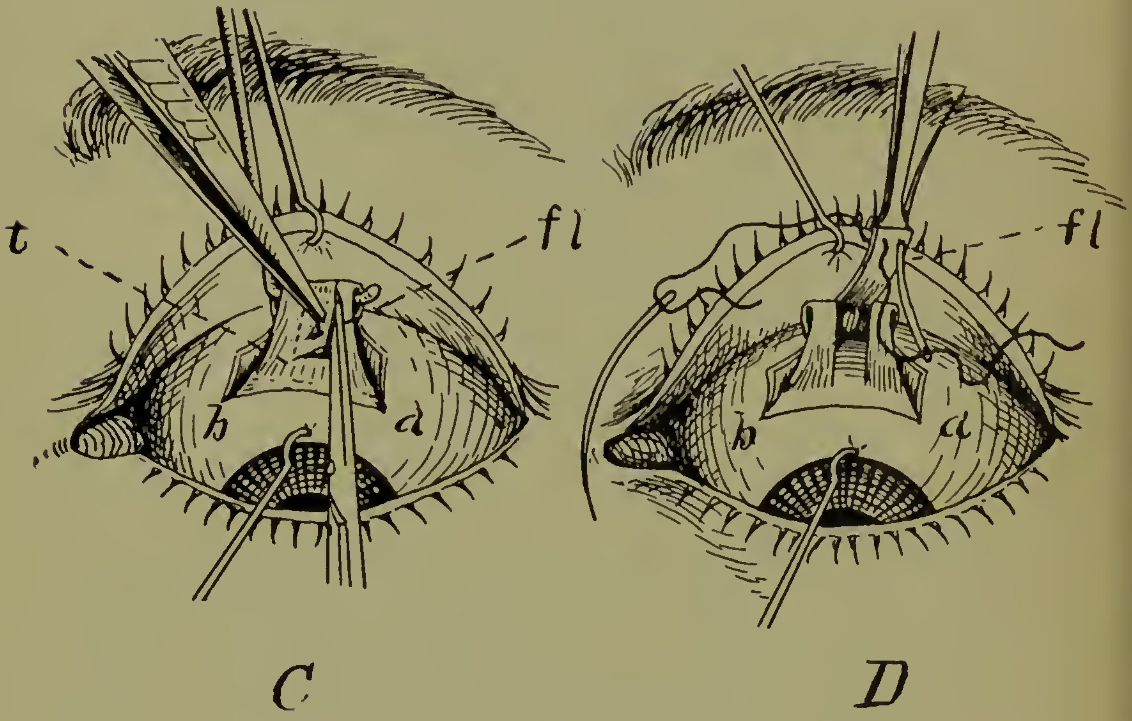


Motais' Operation for Ptosis. A. First Stage.

b, *a*, transverse incision in the conjunctiva, 7 mm. above the cornea. From the middle of this incision another extends to *c*, at the superior tarsal border. B. Hook holding up the tendon of the superior rectus.

The needles are now passed into this little pocket, and come back through the tarsus about 2 mm. from its superior border; the little tongue of tendon is drawn onto the anterior surface of the tarsal plate; the sutures are tied on the conjunctival surface. To avoid accident to the cornea from the knot, the needles may be passed through the skin, to emerge just above the lashes, about 4 mm. apart, where the suture may be tied over a roll, as shown.

If the effect on the ptosis is sufficient, the surgical knot in the suture is completed. If the lid is not sufficiently elevated, the little tendinous flap is withdrawn and the loop suture placed higher up; or the pocket may be deepened and the little tongue made to take a place nearer the free border of the tarsus. Two or three ponits of sutures are then placed in the conjunctival wound to cover the new tendon.



Motais' Operation for Ptosis. Second Stage.

C. Forming the tongue flap, f, l, 3 mm. wide in the middle of the superior rectus tendon. Lateral incisions in the tendon are 10 mm. long.

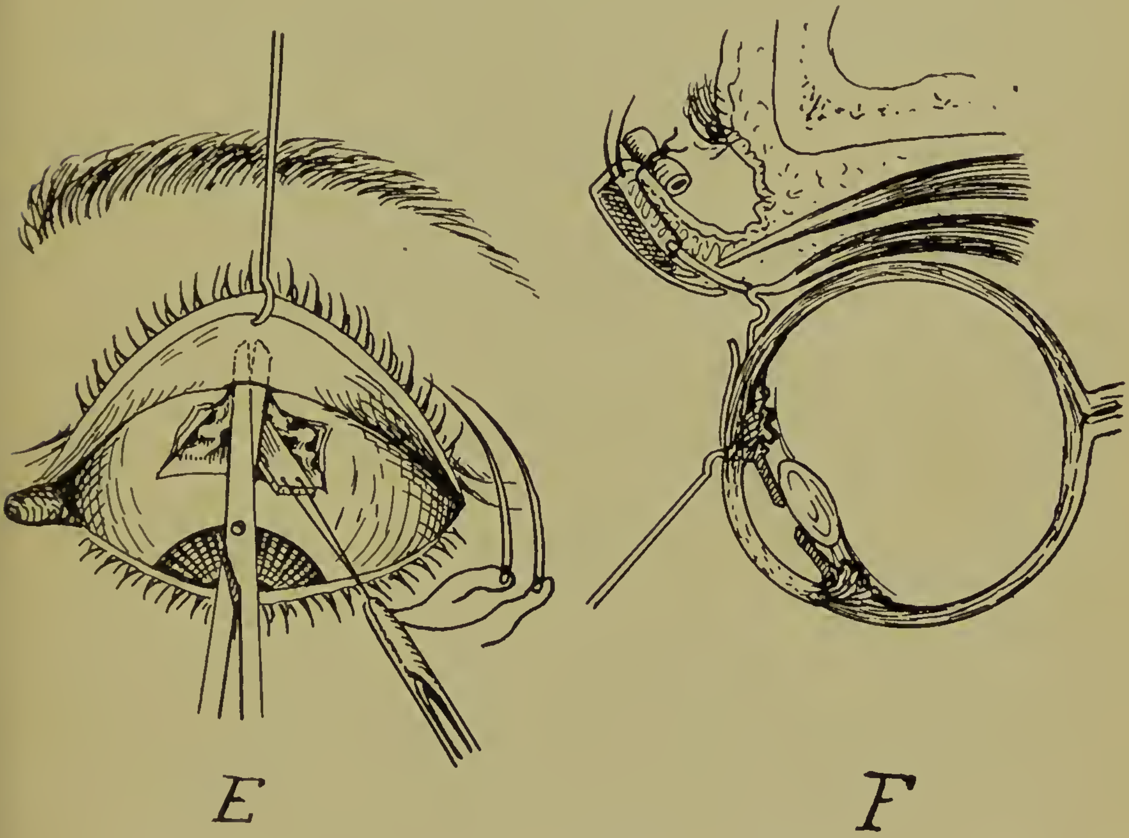
D. Tendon flap, *f*, *l*, held by a fixation forceps, while a loop suture is passed through it, 3 mm. from its end.

Both eyes are closed with a dressing, and the stitches are removed in eight days.

The objection made to this procedure is that a serious vertical diplopia may be caused, because of the inability of the superior rectus to carry the additional weight of the lid and keep up with its fellow of the opposite eye. This, however, does not seem to be the case, according to the testimony of those operators who have had much experience with the operation, and it is even claimed, as mentioned above, that often a weak superior rectus has developed strength under the additional work thrust upon it.

The diplopia, that may be noticed immediately after the operation, usually disappears, or at most, can be elicited only when the eyes are turned strongly upward. This has been the experience of the author in five cases in which he practised the operation, in three of which the technic was modified according to the suggestion of Shoemaker.

Shoemaker (*Annals of Ophthalmology,* Oct., 1907, p. 608), thinks that failure to get the desired result after the Motais operation may be due to the fact that the sutures, if passed through the skin, may attach the tendon flap to the orbicularis muscle and not to the tarsus, as it should be. From the anatomical relation of the parts it is impossible to attach the flap very far below the superior border of the tarsus. To secure an accurate placing of this flap, he sees no objection to an open operation and suggests the following modification: After preparing the tendon flap in the manner that has been described, the lid is returned to its natural position, and a horizontal

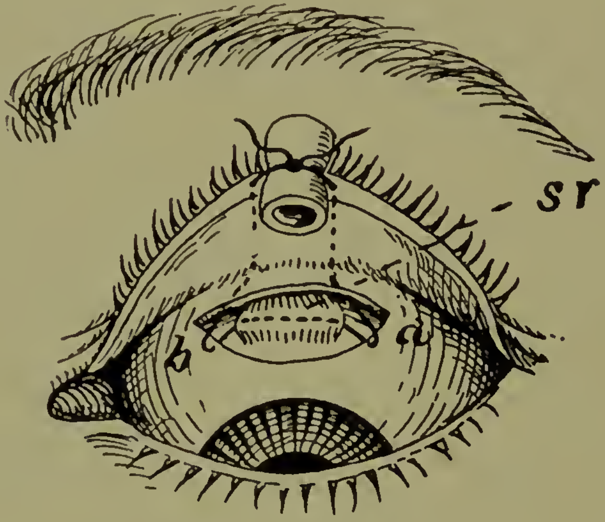


Motais' Operation for Ptosis. Final Stage.

E. Forming the pocket on the anterior surface of the tarsus beginning at the upper end of the vertical incision first made.

F. Diagram of the vertical section through the lid and eyeball to show the relation of the parts after operation.

incision is made through skin and muscle a little below the superior tarsal border. Dissecting back the upper and lower flaps of this wound exposes the superior border of the tarsus, at the upper edge of which a buttonhole can be made through the fascia and levator tendon communicating with the vertical incision already made in the conjunctiva. Through this little opening, the flap can be passed and fastened directly and accurately in place on the tarsus. To do this the loop on the tendon flap should be placed on its upper surface; the needles then secure a hold on the tarsus, and are brought out through the orbicularis and skin, 4 mm. apart, and are tied over a roll. Two fine sutures unite the skin wound. The author has followed this technic in three cases, and can testify to the value of the modification.



Parinaud's Operation for Ptosis.

a, b, incision in the conjunctiva, 12 mm. in length, near the superior border of the tarsus, exposing the tendon of the superior rectus, *s, r.* The suture is passed beneath the tendon, then through the lower lip of the conjunctival wound; then along the anterior face of the tarsus, as indicated by the dotted lines.

In addition to this suggestion of Shoemaker, in order to prevent the fine sutures that pass through the tendon flap from cutting loose because of the tension, the author seized the levator tendon and fascia on each side with loop sutures brought out in the skin of the lid above the cilia, after the manner of Eversbusch. This gave support to the lid while the tendon flap was healing in its new position.

Parinaud's operation (*Annales d'Oculistique,* 1897, Vol. CXVIII, p. 112). This operation consists in uniting the tendon of the superior rectus with the superior border of the tarsus by means of a loop suture. The lid is everted and the tarsal border is held with a tenaculum or with fixation forceps, and the eyeball is drawn downward with another tenaculum or with forceps. An incision is then made with scissors in the conjunctiva, 12 or 15 mm. in length, near the superior border of the tarsus. (See fig. a, b.) The conjunctiva is separated so as to expose the superior rectus tendon. This is seized with toothed forceps and one needle on a double-armed suture is passed under it, including also the capsule on either side. The needles then pass through the lower lip of the conjunctival wound (to close it), then beneath the upper lip of the wound to penetrate the tendon of the levator and glide along the anterior face of the tarsus, to emerge 7 or 8 mm. apart, in the free border of the lids, just in front of the lashes. They are tied over a roll of gauze with a bowknot, drawing them sufficiently to raise the lid.

The effect can be increased or diminished at the next dressing. The sutures are allowed to remain for five or six days.

In cases of paralytic ptosis, a portion of the superior border of the tarsus may be excised with curved scissors, to enhance the effect and this will also facilitate the introduction of the sutures.

SUMMARY.

It will be seen from the number of operations that have been devised for its relief, that ptosis is a condition not easy to remedy.

Of all the operations that have been described those of Motais and Parinaud seem to approach more nearly the ideal, theoretically at least. As Shoemaker has remarked, the successful performance of these operations amounts to a fixation of the eyelid to the eyeball at a point a little above the insertion of the superior rectus.

In many cases, especially of complete ptosis, it might be a serious question whether the superior rectus could ever adapt itself to the new load. When it does, the ideal result is obtained; that is, the lid is raised so that vision is not interfered with, and follows the movements of the eye upward and downward.

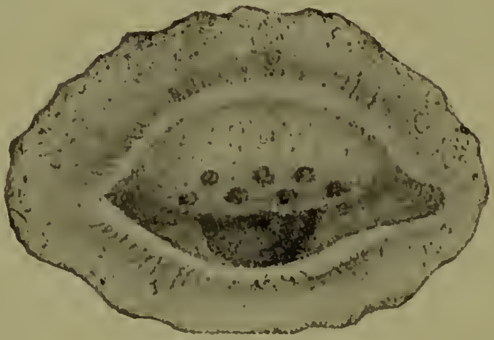
If the superior rectus is too weak to accomplish this, then annoying diplopia would follow, with possibly an apparent downward squint.

It would seem, theoretically at least, in cases of complete ptosis, that a combination of the Motais and Parinaud principle with that of shortening the lid by excision of a strip of the tarsus, after the manner of de Grandmont, in Class III, Group c, would be an improvement on each. Or the Motais operation might be combined with one of the deep-suture operations for supporting the lid, and thus a great part of the weight of the lid would be taken off the superior rectus. This could readily be done if the operation of Motais were made by the open method, after the suggestion of Shoemaker; at the same time gathering sutures could be placed in the tarso-orbital fascia, to shorten it and thus help to correct the ptosis. As said before, the Motais-Parinaud principle is not applicable to cases in which the superior rectus is very weak, as in some cases of paralytic ptosis, or to cases in which this muscle is congenitally defective.

In such cases one would probably have to resort to some operation described in Class II.

When the ptosis is partial, and it can be shown that the levator still has power, an operation of Class III, for advancement of the point of insertion of the levator, may be employed.

Of these the operation of Eversbusch (folding the tendon), of Lapersonne (dividing the tendon and giving it a new point of insertion on the tarsus) and of de Grandmont (excising a strip of the tarsus), are probably the best and the simplest.—(W. H. W.)



Wray's Method of Treating Ptosis.

Everted upper lid, showing parts touched by cautery.

Other new operations for the relief of drooping lids have been devised from time to time. The literature on the subject generally deals, however, with some slight modification of a previously well known ptosis operation.

Ptosis treated by the cautery. This form of treatment is advised by Wray (*Prac. Med. Series,* Eye, p. 56, 1910). The lid is everted so as to expose the attachment of the levator to the upper margin of the tarsus. The region is then punctured with the actual cautery. The holes are burned in rows. The number of holes corresponds to the amount of effect desired. The same procedure can be carried out through a skin incision in the lid. If the latter method is adopted, cocain can be injected subcutaneously; if by way of the conjunctival side of the lid cocain should be first instilled. See the cut.

Thomson's operation. A modification (*Annals of Ophthalmol-*

ogy, October, 1905), of the operation by Wolff is preferred by Thomson, of New York. An incision is made through the skin parallel to, and extending the full length of, the upper tarsal margin. The skin is then dissected from the underlying parts, downward to the lid margin and upward to the brow. Vertical incisions are made through the orbicularis on either side of the levator, and this strip of orbicularis removed. The levator is now separated from the conjunctiva as far back as possible. The tendon is grasped and severed from its tarsal attachment. From 1½ to 3 mm. of it is excised, and then reattached by mattress sutures to the tarsus near its ciliary margin. Silk is used for the suturing. The skin wound is closed after a small strip of skin is removed and the part covered with a dry dressing. The author claims that this operation works well even in the presence of an atrophic muscle, and that it is especially indicated in monocular ptosis.

Fergus (*British Med. Jour.,* May 16, 1908), has compared his own device with those of other operators. First of all the operations of Dransart, Pegenstecher and Hess, that depend upon the production of cicatricial contraction. 2. Procedures which leave ligatures permanently embedded in the tissues, as in the operations of Mules, Worth and Harman. 3. Attempts at the advancement of the occipito-frontalis, or attaching the superior rectus to the upper lip; others have advanced what they believe to be the levator palpebræ superioris. 4. Plastic operations, such as that described by Panas. Fergus greatly objects to the unsurgical method of those operations which depend upon cicatricial contraction with sutures, for unless they become septic they are useless. He prefers the advancement operations. He has had marked success by his method.

Bettremieux (*Oph. Year-Book,* p. 388, 1912), advocates using the frontalis instead of the superior rectus. He passes two sutures subcutaneously and ties them over a small tampon of absorbent cotton. The sutures should be left in place for several weeks until solid, cicatricial contraction has taken place. He reports a case of congenital ptosis accompanied by spasm of convergence and accommodation upon attempts at raising the lid, due, he believes, to an overflow of nerve impulse accompanying the effort to lift the lid so as to free the pupil.

Stevens makes an incision along the whole length of the border of the lid as near as possible to the cilia, but avoiding injury of the roots of the lashes. The skin is then dissected up so as to uncover the whole of the cartilage. The attenuated fibers of the elevator muscle are separately dissected from their attachment to the cartilage, after which one-half dozen very fine sutures attach their free extremities to the tissue just above the original line of incision.

Komoto (*Cent. prakt. Aug.*, 36, August, p. 225, 1912), devised a new method, by transplanting a strip of skin, without epithelium, under the lid for creating a direct connection between the ciliary margin and the skin of the forehead. A piece of skin, 1.5 cm. wide and 4 cm. long, is cut from the upper arm, after removing the superficial epithelial layer with a scalpel and detaching the subcutaneous adipose tissue with scissors. One end of the excised strip is split into two parts, and each end provided with a double-armed thread. Then a crescent of skin close to the border is cut from the upper lid and each leg of the strip is sewed to the lid border. The thread of the other end of the strip is now brought into the eye of a very broad, curved needle. This needle is carried with a needle-holder from the wound under the skin to the eye-brow. The strip is now pulled up until the palpebral fissure has the desired width, and sewed into the wound of the skin. The eye is dressed with borated vaselin and the sutures are removed after a week. As the transplanted skin is apt to shrink and thus increase the initial result, Komoto advises us to make the palebral fissure small in the first instance.

E. Machek (*Tygodnik lekarski,* Nov. 5, 1912), describes his operation as follows:

The first cutaneous incision is made 6 mm. above the free border of the upper lid and parallel to it; the second, slightly longer, is parallel to the first and is made 5 to 6 mm. above it. The resulting horizontal band is now divided vertically into two equal parts, making two rectangular flaps, which are next dissected up to the outer and inner angles. A pointed bistury is now plunged under the skin at the temporal extremity, then at the nasal extremity, making two subcutaneous canals, emerging vertically on a level with the brow. Into these two subcutaneous canals the two flaps are now introduced, guided by threaded needles, and they are then pulled upward as much as is necessary to obtain the required elevation of the lid, after which they are fixed by sutures at the emerging point in the brow. The skin of the upper part of the lid then covers the lower denuded portion, forming a kind of apron which perfectly imitates the normal fold, consequently no sutures are required in the palpebral incisions. Machek's operation differs from that of Panas, in that, instead of a single large and central flap, there are two lateral and straight flaps. This procedure is said to offer an immediate cosmetic effect, which is lasting and remains definite. A slight degree of overcorrection should always be made, with a corresponding slight lagophthalmus, which disappears in a few days.

An easily-performed operative procedure based, as the author observes, on the methods of Hotz, Eversbusch, de Grandmont and Gruening, is described by J. H. Claiborne (*Ophthalmology,* July, 1914.)

The skin being smoothed, the entire lid is clasped with a large clamp. A straight incision is made from 3 to 4 mm. from the free palpebral border across the extension of the clamp. An elliptical incision connecting the inner and outer end of the first incision exposes the tarsus, the skin removed depending in size to some extent on the effect desired. Generally, it should be from 5 to 8 mm. at the highest point of the curve. A piece of tarsus including the conjunctiva from 12 to 15 mm. in length and 2 to 3 in breadth, parallelogram in shape, is removed, a distance of 3 to 4 mm. from the inferior cutaneous lip, thus fenestrating the tarsus. The whole length of the fenestrum as shown in the cut is too long, though its position is exactly correct. Five stitches are used, a central and four lateral ones; the central stitch being of slightly stouter thread than the others. The needle is passed through the center of the lower skin wound, about 2 mm. from the edge; it is again grasped by the needle holder and a deep orbital vertical stitch is taken in the tarso-orbital fascia; this is facilitated by insinuating the forceps underneath the upper skin lip and slightly lifting it, so as to expose the tarso-orbital fascia; again the needle is drawn out and is grasped by the holder; the last stitch is taken through the upper lip about 2 mm. from the edge, so that the needle has been inserted three times—the first through the lower cutaneous lip, the second in the subcutaneous tarso-orbital fascia, and the third through the upper cutaneous lip—all three stitches lying in the same vertical plane. Let it be remembered that the needle is grasped anew for each stitch—otherwise the result is not obtained; four lateral stitches are inserted in like manner. The clasp is then removed and the stitches are tied so that there is no buckling of the skin wound. It will be observed that no stitches have been taken in the tarsal wound. While this operation may not be considered entirely original, it is entitled to be classed by itself for several reasons.

In Gruening's operation an elliptical piece is removed from the tarsus: the piece taken from the tarsus in this operation is parallelogram shaped, and is slightly shorter than that in the operation of Gruening; in addition, no skin is removed in his operation, while the stitches are put in the tarsus, the skin wound falling together by reason of the closing of the lips of the tarsal wound.

After healing, if the lid be turned, a slight buckling of the tarsal wound will be noticed. This produces no discomfort, or any other effect on the eye.

M. Marquez (*Archivos de Oftalm Hip.-Am.,* Jan., 1915; review by Grimsdale, *Ophthalmoscope,* p. 418, Aug., 1915), describes the ptosis operation of his devising as follows. The upper lid is everted and drawn up by means of a small sharp hook fixed in the lid near the free margin. The eye is drawn down by a second hook in the upper part of the sclero-corneal junction; and by these means the superior fornix of the conjunctiva is obliterated. An incision is made horizontally about 7 mm. or 8 mm. from the cornea over the insertion of the superior rectus and a second vertically backwards from the first to the upper border of the tarsal "cartilage"; here a third incision is made horizontally along the border of the cartilage. The conjunctiva is then dissected back, and the underlying capsule of Tenon divided. A squint hook is then passed from without inwards under the tendon and slipped up and down for a distance of about a centimeter, so as to separate it entirely from the globe. Marquez, then, by the aid of a sharp-pointed hook, separates the inner from the outer half of the tendon and passes the sutures which will be used to fix the flap in position before he divides the flap from the sclerotic. He then cuts with scissors through the fascia above the tarsal plate and dissects down through the soft tissues between the plate and the skin almost to the free margin of the eyelid. The sutures are then passed down in this space and tied on the skin surface.

Roberts (*Ophthalmic Year-Book,* p. 292, 1916), to remedy an aggravated congenital ptosis, following a rather unsatisfactory result by Wilder's method, devised the following: After exposing the occipito-frontalis muscle and tendon, and by a separate incision, also exposing the tarsal plate of the upper lid, leaving a bridge of tissue between the two incisions, he cut a muscular flap from the belly of the occipito-frontalis muscle. He then turned the flap downwards and thrust it through a tunnel beneath the bridge between the two incisions, and sutured the flap to and on the upper edge of the exposed tarsal plate. Returning to the upper incision, two strips each half the width of the inverted flap having their only attachment to the muscle above, were cut on each side of the turned down flap which had been united to the tarsal plate. These strips were drawn toward the fold of the inverted flap, attached to it on its superficial surface, which formerly had been the under surface, by a mattress suture at each end, and united in the middle line by a third suture also put through the turned-over portion of flap. An additional suture was inserted at one edge where the first flap was bent over to keep it thus folded. The result was very satisfactory, not only in enabling the eyelid to be raised, but leaving a normal furrow in the lid at the upper edge of the tarsal plate.

Ptosis adiposa. See **Blepharochalasis,** p. 1033, Vol. II of this *Encyclopedia* where the various "false" forms of ptosis are discussed. The term *ptosis adiposa* is, however, usually applied to the condition in which a fold of the upper lid skin sags down and hangs over the free border of the upper lid.

This matter is further discussed by Weinstein (*Klin. Monatsbl. für Augenheilk.,* Oct., 1907; review by Traquair, *Oph. Review,* Dec., 1909), who believes that *ptosis atonica* or blepharochalasis and *ptosis adiposa* are different manifestations of the same atrophic process, and gives an account of a case.

Sichel in 1844 described ptosis lipomateux as a modification of ptosis atonique and distinguished both from ptosis paralytique. In ptosis atonique, according to this writer, the skin of the upper lid is flabby and shrivelled, sometimes presenting transverse folds which may hang down below the free border of the tarsus. On pinching up the skin between the fingers the fold thus formed effaces itself slowly, often not without some manipulation. If this excess of skin is held up the lid recovers its mobility more or less completely. The attempts of the levator palpebræ to raise the lid may be observed beneath the skin. Both eyes are usually affected.

Ptosis lipomateux resembles the atonic form, but here the skin is smooth and distended, presenting a somewhat elastic swelling. Between the skin and the orbicularis palpebrarum there is a deposit of fat most frequently continuous with the orbital cellulo-adipose tissue, which separates the fibres of the muscle and penetrates between them to its position beneath the skin. Usually this mass is enclosed between the edge of the lid and the covering fold, often however it hangs in front of the lower part of the lid like a pad or a little transverse sac. The weight of this mass impedes the movements of the lid.

Cases recorded by later writers are quoted and one or two points are added to Sichel's description. The author attaches importance to certain features common to both affections: the integrity of the levator palpebræ, the time of onset—youth or early adult life, the occasional occurrence of prolapse of the lachrymal gland, sometimes unilateral, more often bilateral, and, in ptosis adiposa, to the fact that the fat found beneath the skin of the lid has no capsule but is continuous with that of the orbit.

The case which he describes presented features similar to those of

Sichel's ptosis lipomateux. A peasant, 21 years old, was afflicted with steadily increasing swelling of the upper lids of six years duration. When the eyes were opened the atrophic skin of the lids hung down over their free borders and fatty tissue could be felt through it. Externally and a little below the orbital margin on each side the lachrymal gland could be felt as a soft, elastic, oval body, the size of a raisin, freely moveable in all directions, especially upwards. The fat was found to have no capsule and to be continuous with the orbital fat.

Weinstein holds that the same atrophic process is responsible for both conditions. When the skin is affected ptosis atonica or blepharochalasis is produced, and, by the spread of this atrophic process to the deeper connective tissue of the orbit, the orbital fat is permitted to pass forwards between the fibres of the orbicularis to a position beneath the skin of the upper lid, then falling down over the tarsus producing the picture of ptosis adiposa. In a similar way the supports of the lachrymal gland may be loosened permitting it to prolapse.

As regards the etiology of this atrophic process the author admits that we are completely ignorant. He would group it along with idiopathic progressive atrophy of the skin, paralytic erythema, erythromelalgia and chronic progressive acrodermatitis, and suggests the term *ptosis atrophica* instead of ptosis atonica. In some cases nervous, especially vasomotor, disturbances have been observed, and many writers have attached importance to the influence of physical excitement.

Of the authors quoted only Loeser affords complete support to Weinstein's view. Others have not insisted on the close relationship of the two conditions, regarding the presence of fat in the lid as due to a fat-hernia or to hypertrophy of the subfascial fat, and the prolapse of the lachrymal gland as an accidental complication or a congenital anomaly.

The author is not prepared to deny the possible existence of a form of ptosis adiposa depending upon a true hypertrophy of the subfascial fat without atrophy of the skin of the lid.

Ptosis amyotrophica. A term applied by Goldzieher (*Centralbl. für pkt. Augenheilk.*, Feb., 1890) to a very rare, isolated, generally bilateral, slowly progressive form of the disease usually occurring in old age, in which all the tissues of the lid undergo atrophic changes. See, also, **Ptosis, Progressive.**

Ptosis atonica. See **Blepharochalasis.**

Ptosis, Central. Falling of the lid due to lesions of the central nervous system. See p. 1958, Vol. III, of this *Encyclopedia*.

Ptosis, Congenital. See p. 2797, Vol. IV of this *Encyclopedia*.

Ptosis cutanea. A name given by Panas to blepharochalasis. See p. 1033, Vol. II, of this *Encyclopedia*.

Ptosis, Family. Although rare, yet well marked family inheritance of this congenital defect is on record. The *Journal of the Am. Med. Assocn.*, p. 1553, May 13, 1916, chronicles the chance discovery of four generations of congenital ptosis ("slit-eyes") in northern Georgia by the horticulturist of the Georgia Experiment Station. The interest in the Georgia record lies in the long succession of cases of direct relationship. They include, among the actually known descendants exhibiting the lid defect, three great-grandchildren, six grandchildren, a son and his father. Among the children involved are both boys and girls, so that the defect involving the musculature of the upper eyelid cannot be regarded as sex-linked in its inheritance, as are color-blindness and one form of night-blindness. One cannot build hypotheses from a paucity of data; nevertheless the history here quoted might give rise to a suspicion that the trait is what students of heredity term a "simple Mendelian recessive." On this tentative basis, current theories would suggest either the absence of the factor for the normal development of the lid muscle or the presence of an inhibitor of normal development.

Sachs saw congenital ptosis and epicanthus in three sisters, whose father had also suffered from congenital ptosis. In the family history of congenital ptosis, reported by Ginzberg, the first child was normal, the second had unilateral ptosis, the third very pronounced bilateral ptosis, the fourth moderate bilateral ptosis, and the fifth was normal. The parents were healthy and the history was negative.

Addario La Ferla describes ptosis as a congenital defect in three successive generations. His personal patient was a girl of 15 years. She and her paternal grandmother had complete bilateral ptosis, while her father had an incomplete ptosis. The paternal and maternal grandfathers were distant blood relatives. See, also, under **Ptosis.**

Ptosis hysterica. FALSE PTOSIS. This form of hysteria is thought to be due to orbicularis spasm, which may be either tonic or clonic. See p. 6124, Vol. VIII of this *Encyclopedia*. See, also, **Ptosis,** as well as **Ptosis, Spurious.**

Ptosis iridis. Hernia of the iris.

Ptosisklemme. (G.) Ptosis spectacles or prop.

Ptosis lipomatosa. SYMMETRICAL LIPOMATOSIS OF THE LID. This condition is seen when, in consequence of individual peculiarities in the orbital fascia, or from transference of the disease process to this structure, prolapse of the orbital fat occurs. If the prolapse of the fatty tissue is of a high degree, a condition is seen which may be termed "fat hernia" of the upper lid.

Ptosis, "Morning." Matinal ptosis. A neurasthenic condition present when the patient (usually an anemic woman) rises in the morning, passing off as the day advances. The name was applied first by Gowers.

Ptosis, "Night." A term applied by Weir Mitchell to that form of drooping lids observed in neurasthenics who cannot keep their eyes open as night approaches.

Ptosis paralytica. The form of the disease due to paresis or paralysis of that branch of the third nerve supplying the levator palpebræ muscle. See **Ophthalmoplegia.**

Ptosis, Progressive. This is probably but a synonym for ptosis amyotrophica. E. Treacher Collins (*Ophthalmic Record,* June, 1909), describes an example in a woman who came for advice, suffering from defective sight and inability to open the eyes. She had never been able to open the eyes properly, but this difficulty had increased considerably during the last 30 years, as shown by photographs taken at intervening periods. The ptosis was more marked on the left side than on the right, and there was some sinking in of the skin immediately beneath the upper margin of the orbits, indicating some absorption of orbital fat.

Both corneæ showed symmetrical changes, a central oval portion alone preserving its transparency. The boundaries of the normal cornea could be made out though of an opaque and greyish appearance. Bloodvessels proceeded over the cornea from the conjunctiva. An opaque ring, like an arcus senilis, bounded the greyish area all round and was separated from the peripheral opacity by a semi-clear space like that seen with a normal arcus. There were some central lens opacities, and the vision was 6/12 with correction in the right and 6/12 minus in the left.

Cases of progressive bilateral ptosis have been described by Fuchs (*Arch für Ophth.*, xxxvii, p. 234), all 5 being females. Beyond this, Collins could recall only one case of a similar nature, described and figured in the *Trans. of Ophth. Society,* vol. xxiv, p. 45, in a man aged 21.

Ptosis prop. A mechanical device, usually some form of spectacles, for holding up the falling eyelid. Rayner Batten (*Ophthalmic Review,* p. 29, Jan., 1910) describes an orbital frame for eyeglasses adapted for this purpose. These orbital eyeglass frames depend for their attachment to the face on two rigid or nearly rigid wires attached to the lower part of the frame and accurately adjusted to the nasal margin of the orbit, and terminate in a free end lying immediately beneath the upper margin of the orbit. They are dependent, not on a spring, but on the accuracy of their fit; and by virtue of their application to the orbital margin require a more or less prominent eyebrow and a deep set eye. See, also, **Ptosis.**

Ptosis senilis. The ptosis of old age; sometimes regarded as a form of *ptosis atonica.* In elderly people a slight ptosis may be present as a symptom of uncorrected presbyopia.

Ptosis, Spurious. FALSE PTOSIS. PSEUDO-PTOSIS. HYSTERICAL PTOSIS. Falling of one or both upper lids as a manifestation of hysteria is not very uncommon. See **Ptosis, Hysterical.**

An example of pseudoparalytic (hysterotraumatic) ptosis following an injury is cited by Bettremieux (*Clique Ophtalm.,* May 10, 1907.) The patient, a carpenter 22 years old, was injured March 10, 1906, by the falling of a heavy piece of wood which produced a right fronto-parietal contusion with cerebral concussion. The injury did not seem to produce any serious consequence, and at the end of March the man returned to work. He complained in April that the vision of the right eye had diminished, and the question was raised as to whether there was an optic nerve lesion. Bettremieux saw the case May 3 and found a complete closure of the right eye, with lowering of the corresponding eyebrow, which eliminated the diagnosis of a true ptosis. There was no appreciable lesion discovered by ophthalmoscopic examination. The pupillary reflex was normal; patient complained of a pronounced amblyopia of the right eye. From several proofs of simulation, Bettremieux believed that the amblyopia was feigned, and two confreres confirmed that opinion, which was based on the fact of the association in the same subject of hysterotraumatic blepharospasm and simulated amblyopia. Such a combination would be an exception to the rule of Parinaud, that amblyopia or amaurosis does not occur with blepharospasm. There was anesthesia of the pharynx and nearly complete right hemianesthesia, with a few zones of intermittent sensibility; the knee tendon reflex was normal; the right plantar reflex was suppressed. The visual acuity of the left eye was normal; the limits of the field for this eye were approximately the same for all directions: 30 degrees for white, 20 degrees for red and green, and 10 degrees for blue. Medical treatment and electrization gave no result. Operation for ptosis was refused.

Laignel-Lavastine and Ballet (*Ophthalmic Year-Book,* p. 291, 1916) report a case of pseudo-hysterical ptosis, first described by

Charcot and Parinaud, lids falling without folds, head thrown backward, contraction of the frontalis on attempts to open the eyes, dropping of eyebrow. This faulty habit, consecutive to an insignificant traumatism, partly disappears under compression of the eye. The functional oculo-palpebral synergism (opening the left eye on compression of the right) is not explicable by any nervous connection. It resembles the ordinary synergism of a marksman taking aim, the palpebral aperture of whose aiming eye widens during contraction of the orbicularis of the opposite side.

False (i. e., non-paralytic or non-congenital) ptosis may also be seen in patients with lid tumors and palpebral inflammations.

Ptosis sympathica. A name given by Horner and Stellwag to a rare form of ptosis due to paresis of the cervical sympathetic nerve, occurring in connection with miosis and vascular paralysis of the side of the face affected.

Ptosis traumatica. A form of the disease due to injury.

Ptosis, Unilateral. This may be a genuine traumatic, paralytic sequel of instrumental delivery. It is the form usually associated with jaw-winking and with tumors and chronic infections of the upper lid.

Ptotic. Pertaining to or affected with ptosis.

P. T. R. Abbreviation for *Ger. Perlsucht Tuberculin Rest*, a tuberculin prepared from bovine bacilli in the same manner as Koch's new turberculin.

Puberty, Ocular diseases of. Although Parsons (*Pathology of the Eye*, p. 1303) quotes a number of observations that seem to confirm the contentions of the early writers that the adolescent changes that accompany puberty are causes or coincidents of eye disease, it cannot be said that they really stand in the relation of cause and effect. See, for example, **Adolescence, Cataract of,** p. 102, Vol. I; also, **Childhood, Diseases of,** p. 2057, Vol. III of this *Encyclopedia.*

Puddlers, Eye diseases of. Ocular affections of workers in glass factories and iron foundries who are exposed to the intense glare and heat of furnaces have been considered under **Dazzling,** p. 3778, Vol. V; **Glassblower's cataract,** p. 5395, Vol. VII, and similar captions in this *Encyclopedia.* Electric welding is one of the objectionable occupations from this standpoint when there is not adequate protection for the eye.

Bernard Cridland (*Ophthalmoscope,* p. 126, March, 1915), draws attention to the fact that the occupation of a "puddler" is one, which, for a considerable time during the day, involves the exposure of the eyes to a combination of intense light and heat. He has to look, almost continuously, at molten iron through a small rectangular opening, during a period of from one to two hours. The period is called a "heat," and there are six or seven "heats" in a day, with, as a rule, a half-hour interval between each.

Practically, none of the men wear (especially in Great Britain) protective goggles of any kind, so that the full force of the light and heat falls directly upon the eyes.

A good example of the effects of puddling on the eyes was that of M. F., aged 50 years, for thirty years a "puddler," who presented himself complaining that his vision had steadily diminished for a year, especially during the past month. There was no history of previous ocular trouble, and no family history of cataract.

The man himself was healthy, but looked older than his years.

On examination of the eyes, the lids and conjunctivæ presented the weather-worn appearance of those of a man engaged in a dusty trade. Both corneæ were clear, the anterior chambers normal in depth, the irides sound and the pupils reacted well. Through the undilated pupils (rather small) the lenses appeared greyish-white, as though mature senile cataracts were present in each eye, but on dilation with homatropine and cocaine, both were seen to present the type known as "glassblowers' cataract." The right lens showed a moderately dense posterior polar and cortical opacity, surrounded by a less dense area with a well-marked irregularly-circular outline. The periphery of the lens showed some dot opacities with several striæ downwards and inwards and a few scattered smudges elsewhere. A moderately clear view of the vitreous and fundus was obtainable; they appeared normal. The left lens, as compared with the right, showed a much denser posterior polar and cortical opacity, surrounded by a less dense area with a well-marked circular outline, the extent of which, however, was less than that of the right lens. Some striæ and dots were to be seen in the comparatively clear periphery. The vitreous was clear and fundus normal. The vision of each eye with the undilated pupil had been reduced to ability to count fingers at two feet, but was distinctly improved by dilation.

Such cases are by no means common. The writer, who had opportunities of examining many such iron-workers was unable to recall more than four or five others in the past ten years.

If it be true in the case of glassblowers that this type of cataract is directly due to the occupation, and there is no reason to doubt it, it should equally be held that in the case of a "puddler" developing the type, the occupation is responsible, for the working conditions are so similar.

The "puddler," then, becomes entitled to the same compensation (all too small) that the glassblower, so afflicted, enjoys under the British Workmen's Compensation Act.

The addition of the "puddler" to the glassblower in the industrial disease schedule would mean a small matter to the employers, for the number of cases is small, but to the individual concerned it would mean the difference between pauperism and ability to hold on until a successful operation restores useful sight to him and enables him to do some work.

In the event of it being generally accepted that this type of cataract can occur in trades other than that of the glassblower (in America this is already so), a more scientific term might be adopted to distinguish the characteristic posterior polar opacity which follows the prolonged exposure of the naked eye to intense light and heat.

The term "light cataract" or "heat cataract" would indicate that light rays alone, or heat rays alone, were the etiological factor, but as this has not been decided, Cridland suggests the term "ray cataract," as being an inclusive one and indicating that the etiological factor was the action of heat or light rays, or of both, as the case may be.

The same writer (*Ophthalmoscope*, p. 25, Jan., 1916), gives an account of a second case in an iron-smelter.

T. W., æt. 66, had worked as a puddler for 48 years and had never been in a glass-furnace. During his work he had not worn protective goggles. See **Pugh glasses.**

When first seen he complained that his vision had been failing for the past three or four years, but that there had been no alteration since January last, when, on account of his faulty vision, he had been forced to give up his work.

On examination, both conjunctivæ presented the chronically inflamed appearance usually met with amongst iron-workers. The corneæ were clear; irides normal and reacting fairly well. The vision of each eye was 2/60th, not improved by glasses. Through the undilated pupils, the lenses presented the appearance of nearly mature senile cataracts.

The right lens showed, through the dilated pupil by the oblique illumination, a central nuclear haze with (situated at the posterior pole and lying in the most posterior layers of the cortex) a small dense opacity, oval in shape, with long axis horizontal. Its center was clearer than its edge, which was well-defined, but occupied by a smaller ring concentric with it and apparently lying in a plane posterior. The peripheral part of the lens was comparatively clear, although showing radial striate opacities.

With the ophthalmoscope the small central opacities could not be detected, but instead there was seen a somewhat dense opacity roughly quadrilateral in shape and occupying a much greater area. The left lens presented much the same appearance, namely, small central ring opacities by oblique light and a larger less dense opacity, quadrilateral in shape with the ophthalmoscope. On the whole, this lens was more opaque than the right and the radial striæ at the periphery were more marked. Both fundi were easily examined through the peripheral portions of the lenses and showed no lesions. The first case had been successfully operated on. No needling was found necessary, notwithstanding the comparatively large amount of clear lens substance present in each. A perfectly clear view of each fundus was obtainable. R. V. on correction equals 6/12. Fundus normal, and there was no apparent reason why the vision should not be better. The question, therefore, arises whether a lesion of the retina at the macular region or in the nerve may not be present in addition as the result of the prolonged exposure to heat and light rays.

Puerperal amaurosis. See **Pregnancy, Eye complications of.** To what is found there and elsewhere in this *Encyclopedia* may be added the observations of Sydney Stephenson and W. P. Herringham (*The Ophthalmoscope,* March, 1910). The authors record two cases of puerperal amaurosis.

The first was one of albuminuria and headache in a primipara followed shortly after delivery by temporary blindness without ophthalmoscopic changes. No eclampsia. Recovery.

The second was one of albuminuria, temporary blindness without ophthalmoscopic changes, and eclampsia in a primipara. Recovery.

In the first case a woman of 23 years lost her sight completely and suddenly soon after normal labor, before which she had suffered from severe headaches, and her urine was known to contain albumin. At the same time that her sight was lost she was affected with headaches, vomiting and became semi-somnolent. The pupils retained their direct action to light. Improvement in sight speedily set in. Two days after delivery she had perception of light. On the following day large objects could be recognized. Five days after delivery she could count fingers at six feet and on the next day she could read ordinary newspaper type with one eye. Twenty-one days after delivery vision with correction was R.E. 6/6, L.E. 6/12, 1 letter.

In the second case delivery was by forceps under chloroform. As soon as the patient recovered from the anesthetic she complained of headache and vomited once. It was then found that she was completely blind. The pupils preserved their normal reaction. After six hours of blindness she developed a typical eclampsial fit, which lasted for about a minute and was followed by a period of unconsciousness lasting about 10 minutes. When she regained consciousness sight had returned. Four days after delivery the patient could read and readily distinguish things about the ward. She left the hospital a fortnight later.

About fifty cases are cited from the literature on the subject. In these cases amaurosis or amblyopia, apparently not dependent upon uremia, supervened during pregnancy, labor or childbed. Many were accompanied by eclampsia and nearly all by albumin in the urine. It is probable that the etiology of these cases is essentially the same whether they occurred before, during, or after labor, and the authors make the following comments upon them: 1. The existence in most cases of convulsions—so called "puerperal eclampsia." 2. The presence in the urine, which is usually excreted in scanty amount, of albumin, blood, and various kinds of tube-casts. 3. The existence of headache. 4. The co-existence of edema of the eyelids, face, and elsewhere.

That the defect in sight may be a premonitory sign of puerperal eclampsia is shown in the authors' second case as well as in others cited. It is more common for the amblyopia or amaurosis to supervene after one or more "fits" have taken place.

Eclampsia need not occur, as in the authors' first case, where the blindness alone occurred. The occurrence of eclampsia in some pregnancies and of amaurosis in others is an argument against the dependence of one on the other, and in favor of a common casual factor. Moreover eclampsia may occur in one pregnancy and amaurosis in another as in a case quoted.

Eclampsia, and so amaurosis, according to modern views is due to a poisoning of the mother by products of her own metabolism, and possibly those of the fetus, which her excretory organs are incapable of removing. The amaurosis in association with the severe vomiting of pregnancy is mentioned as being most probably of a similar nature. The authors draw the following conclusions:—

1. That a form of amaurosis or amblyopia, not accompanied by ophthalmoscopic signs, or, at least, by none adequate to account for the condition, may supervene during pregnancy, parturition, or the puerperium.

2. That rarely it may assume the form of a hemianopic defect or of a central scotoma in the field of vision.

3. That it is often associated with such signs and symptoms of toxemia as headache, edema, eclampsia and scanty urine, containing albumin, casts and blood.

4. That it appears to form one of the rarer manifestations of toxemic poisoning.

5. That it is not proved to be dependent upon uremia, although it has usually been confused with so-called "uremic amaurosis."

6. That it recovers, as a rule, completely within a few hours or days.

The paper concludes with a note by Herringham in which he includes notes of three cases more or less analogous to those reported by Stephenson.

In Case 1 there was chronic nephritis, toxic amblyopia and slight choroiditis in a primipara. The patient recovered.

Case 2 was one of eclampsia and amblyopia.

Case 3 was one of puerperal eclampsia and temporary amaurosis.

Chronic renal disease is present in some of the cases of amblyopia associated with pregnancy. He maintains that the subsequent history of good health in so many cases excludes the possibility of it always being present. Moreover albuminuria though almost always, is not always present. He disposes of the contention that the condition is due to an acute or subacute nephritis, by the fact that he has never seen transient amblyopia without fundus changes except in connection with pregnancy.

It occurred to him that it would surely be met with in cases of scarlatinal nephritis if it was associated with nephritis, and he accordingly consulted Foord Caiger on the subject. The latter's opinion founded on his vast and special experience was entirely contrary to the supposition. (J. F. Cunningham; the *Oph. Review,* p. 239, Aug., 1910.)

Boyle records the case of a young married woman whose eyes became inflamed the same day she was delivered of a dead child. She had an old pelvic abscess which had been operated on, whether before pregnancy, Boyle could not say. She had increased temperature with all the other symptoms of puerperal fever. The eyelids were swollen, conjunctiva red and chemosed, cornea commencing to be hazy, anterior chamber very deep, iris drawn back, pupil contracted, and aqueous humor becoming cloudy. Boyle made a diagnosis of metastatic iridochoroiditis. See, also, **Metastasis, Ocular,** p. 7664, Vol. X, of this *Encyclopedia.*

Pugh glasses. These protectives are the American standard for open hearth work. Continuous use by workmen of these glasses has so accustomed them to the effect upon molten metal that they are able to tell when using them just when the metal has been heated to the proper temperature. These lenses are of separate shades of blue for different uses, and for different furnaces.

Pulley suture. A form of stitch used by F. Krauss (*Ophthalmic Record,* July, 1916) for the restoration of the sulcus in extensive symplepharon.

Pulsadergeschwulst der Augenhöhle. (G.) An aneurysm of the orbit.

Pulsatilla. EASTER FLOWER. DANE'S BLOOD. PASQUE-FLOWER. The whole, dried plant of *Anemone pulsatilla* contains tannin and anemonin, a colorless, odorless, insoluble acrid camphor. The N. D. says that there is probably no drug in the pharmacopeia that has been used in so many diseases or had so many virtues attributed to it. We need not be surprised to learn, then, that in medicinal doses of 2 to 5 grains (0.10-0.30) or of anemonin, gr. 1/8 to 1/2, it has been recommended as curative of cataract, especially by those who have not made an extensive study of that particular metamorphosis. (See **Cineraria maritima.**)

Pulsating exophthalmus. PULSATING ANGIOMA. See **Exophthalmus, Pulsating,** p. 4860, Vol. VII of this *Encyclopedia.* In addition to the account there given a number of other observations, since made, may well be published here.

F. Krause (*N. Y. Med. Journal,* p. 877, May 6, 1916), records a case of pulsating vessel in the orbit, probably an enormously dilated branch of one of the ophthalmic vessels, that refused operation and became blind in the affected eye from optic atrophy preceded by orbital edema, fixation of the globe, optic swelling, contraction of the fields, etc.

Zentmayer (*Journ. Am. Med. Assocn.,* p. 163, July 15, 1916), gives a report of two cases in his own practice and finds from their study and that of others—29 in all—that the common carotid was ligated sixteen times, resulting in a cure in seven, improvement in five and failure in four.

Combined ligation of the common carotid and the ophthalmic vein was done once, resulting in a cure.

Combined ligation of the internal carotid and the facial vein was done once, resulting in a cure.

Ligation of the orbital veins was done once, resulting in slight improvement.

Slow ligation of the carotid was done twice, resulting in one cure and one slight improvement.

Ligation of both carotids was done once, resulting in failure.

Compression of the carotid and internal treatment was followed in four cases, resulting in cure in two, improvement in one, and result unknown in one.

Gelatin injections were used in one case, resulting in a cure.

There was no treatment in six cases.

Combining these cases with those analyzed in Bedell's paper, we find that the common carotid artery was tied thirty-two times with cure in twelve, or 37.5 per cent., improvement in twelve, or 37.5 per cent., and failure in eight, or 25 per cent.

The orbital operation, ligation of the ophthalmic vein, was done in six cases (including the case mentioned by de Schweinitz in discussion), with cure in three, or 50 per cent., improvement in one, or 16 per cent., and failure in two (one fatality), or 33 per cent.

Gelatin injections were used in four cases with cure in two, or 50 per cent., improvement in one, or 25 per cent., and failure in one, or 25 per cent.

It is to be particularly noted that in this combined series there are thirty-two cases of ligation of the common carotid without a fatality. Just how frequently late cerebral softening results, it is difficult to say; but if this complication can be averted, as is claimed, by slow ligation, it would seem that inasmuch as death may result from simple ligation of the ophthalmic vein and that late serious hemorrhage into the orbit necessitating ligation of the carotid artery has occurred, and that finally, in traumatic pulsating exophthalmos the lesion is usually an aneurysm of the internal carotid in the cavernous sinus, the order of surgical procedure indicated is slow ligation of the common carotid, followed by ligation of the ophthalmic vein in those cases in which the primary operation fails to effect a cure.

Inasmuch as the results with gelatin injections have been favorable in the few cases in which they have been tried, there can be no objections to their employment if the patient is seen early.

To the foregoing experiences may be added those of J. Ginzburg (*Klin. Monatsbl. f. Augenheilk.*, Dec., 1912, abstract in the *Ophthalmoscope,* p. 17, March, 1914.) He reports a case of pulsating exophthalmos, and discusses the possibilities of treatment in this condition. His patient received a blow on the left supra-orbital region which led to unconsciousness and other signs of basal fracture. The eye on the injured side presented a double choroidal rupture, but was otherwise normal. On the opposite side, exophthalmos developed next day, and nine days later, pulsation of the globe and pronounced pulsation of the retinal vessels. The other symptoms were anesthesia of the first division of the fifth nerve, complete immobility of the eye, loss of pupil light reflexes, total blindness, and the fundus picture of division of the optic nerve in the optic canal, all on the right side. The diagnosis was basal fracture injuring the optic nerve in the optic canal and wounding the internal carotid artery and the ocular nerves in the cavernous sinus.

Treatment by digital compression of the carotid was without effect, and ligature of the right common carotid produced no lasting benefit. Complete disappearance of the exophthalmos, pulsation, murmurs, and other symptoms, followed ligature of the superior ophthalmic vein in the orbit. Vision was, of course, permanently lost, and there was a corneal opacity due to ulceration.

In discussing the operative measures employed in this condition, Ginzburg points out that, while ligature of the carotid gives a fair proportion of good results (64.5 per cent. more or less completely relieved), it is not without danger to life. The actual figures vary greatly in the opinion of different authors, but they work out the average number of deaths as 9.9 per cent., and it is higher in cases in which the ligature has been applied on both sides. The other operations recommended are intra-orbital, and of these the most important is ligature of the superior ophthalmic vein. It is based on the principle that ligature of the efferent vessel from an aneurysmal varix has the same effect as ligature of the afferent. While the orbital operations seem to be free from risk to life, they have led, in about 50 per cent. of the cases, to functional derangements, such as corneal ulcer, immobility of the eye, ptosis, optic atrophy, and glaucoma. In all but a few cases hitherto, ligature of the superior ophthalmic vein has followed ligature of the carotid, and it is impossible to say how much of the good result is attributable to the first operation. We are probably justified in claiming that the most certain way to obtain a good result is to combine ligature of the common carotid and of the superior ophthalmic vein on the same side. This brings about obstruction both of the afferent and of the efferent channels of the varix. It is much more rational than ligature of both carotids, and much less dangerous to life. The superior ophthalmic vein should first be ligatured, and the carotid later, if necessary. Ligature of the superior ophthalmic vein is not an easy operation, and it is not facilitated by Krönlein's procedure. It is perhaps better not to attempt the application of a ligature, but simply to clamp the vein in the depth of the orbit, and leave the clamp-forceps in the wound for some days.

Pulsation, Retinal. ARTERIAL PULSATION. VENOUS PULSATION. CAPILLARY PULSATION. See **Heart disease, Eye symptoms in,** p. 5717, Vol. VIII of this *Encyclopedia;* also **Glaucoma.**

The common occurrence of venous (retinal) pulsation as a normal phenomenon must not be forgotten; as well as the fact that arterial pulsation does not necessarily indicate disease.

By far the most complete account of this symptom is furnished in an essay by Ballantyne (*Ophthalmoscope*, May-August, 1913, reviewed by Walter Parker, *Annals of Ophthalmology*, July and Oct., 1913), in which a description and explanation of the various forms of retinal arterial pulsation and their clinical significance are given.

The pulsation seen in the *retinal arteries* is considered under four heads: (1) The locomotor pulse; (2) the expansile pulse; (3) the capillary pulse, sometimes found in association with these two and therefore described in this connection, and (4) the pressure pulse, collapsing pulse or intermittent inflow.

The *locomotor pulse* consists of a rhythmic displacement of the artery almost synchronous with the cardiac systole, and may be looked for in three different situations: (a) In the artery and its branches on the disc, (b) in the branches as they pass across the fundus, and (c) at points where bifurcation of a retinal artery occurs. Of these three forms of the locomotor pulse by far the most frequently observed is the second. In all three forms the movement consists of a sudden displacement, followed by a less sudden return to the original position. It agrees further with the radial and other arterial pulses in having an interval before each systolic beat corresponding to the long pause of the cardiac cycle. Intermission of the heart beat is often manifested by intermission of the retinal pulse. The locomotor pulse is most readily seen in the curved portions of the arteries near the disc, and is synchronous with the radial pulse.

The *expansile pulse* is seen as a broadening of the blood column and of the central light streak. It is seen equally well in the straightest arteries, and is often found in the finer and straighter branches well out in the fundus. Sometimes the locomotor pulse alone is seen on and near the disc, and the expansile pulse alone in the periphery of the fundus.

Like the locomotor pulse, the expansile pulse shows a more sudden phase (expansion) followed by a less sudden contraction, and then a pause; three phases corresponding respectively to the systole, diastole, and long pause, of the heart. Irregularities and intermissions of the heart's action are also reproduced in similar variations of the expansile pulse.

The *capillary pulse*, when present, is confined entirely to the disc. If the whole surface of the disc is of uniform tint, the pulse takes the form of a rhythmic deepening and lightening of the tint. If, on the other hand, the disc has one part more and another part less vascular, the pulse is seen as a rhythmic extension of the more vascular area, as one sees it under the nail, in the familiar clinical test. The flushing of the disc accompanies the cardiac systole, and blanching accompanies the diastole. The systolic phase is the more sudden, and the diastolic is followed by a pause. The capillary pulse seems to be absolutely synchronous with the arterial pulse and with the radial pulse.

The *pressure pulse* owes its name to the fact that it is brought about by high intraocular pressure, but the terms ''collapsing pulse'' and ''intermittent inflow'' have more descriptive value.

This phenomenon cônsists in alternate filling and emptying of the central ends of the branches of the central retinal artery, and it apparently never extends outside the limits of the disc. The filling is synchronous with the rise of the radial pulse, and the emptying with its fall, and the changes are so sudden that it is difficult or impossible to make out the direction of the blood stream as it enters or leaves the vessel. It presents the appearance of a column of blood flashing suddenly into and out of sight.

Thirty-six per cent. of healthy persons show some form of arterial pulse in the retina, so that the arterial pulse is physiologic in the sense that it is a common occurrence in health.

In order that a pulse should be visible in any vessel, it is necessary (1) that the blood pressure in the vessel should be affected by the pulse wave, and (2) that this should cause a rhythmic expansion and contraction of the vessel, of sufficient amplitude to be visible. There are strong reasons for believing that the physiologic venous pulse is a pulse transmitted through the capillaries from the retinal arteries, and if we accept that view we must assume the existence of a pulse wave in the retinal arteries, but not necessarily one in which force and amplitude of the wave are great enough in relation to the rigidity of the vessel wall to produce a visible movement.

Two factors lie at the back of all these forms of the retinal arterial pulse: (1) the blood pressure in the retinal arteries, and (2) the intraocular pressure. While the ratio between the intraocular pressure and the mean blood pressure in the retinal arteries is fairly constant under physiologic conditions, the pulse pressure is not always constant. Pathologically, also, the pulse pressure may be greatly increased, while the mean blood pressure and intraocular pressure remain normal, as in aortic regurgitation, or the intraocular pressure may be greatly increased, while the blood pressure is normal, as in glaucoma.

The locomotor pulse consists of an expansion of the artery in the long axis, an elongation of the artery. If this occurs in a curved portion of an artery, the result is a displacement of the summit of the curve in the direction of the convexity, a movement much more readily seen than expansion and contraction in the caliber of the vessel. Raehlmann holds that the locomotor pulse is more dependent on rhythmic acceleration of the blood stream. Both factors are probably effective, as the same conditions of the circulation are favorable to both, the pulse pressure varying directly with the acceleration of blood flow produced by each pulse wave. The tendency of sudden acceleration of the blood stream is to straighten out the vessel, while in the more commonly observed form of locomotor pulse, there occurs an exaggeration of the curves, which can only be due to the elongation of the vessel which results from the systolic rise of blood pressure.

In view of the uncertain results of pressure experiments in the human eye, and the absence of clinical evidences of variation of the locomotor pulse in cases with marked variations of the intraocular tension, it must be admitted that there is no obvious relationship between the locomotor pulse and the pathologic changes in intraocular pressure. The locomotor pulse as a pathologic phenomenon appears to depend almost wholly on an abnormality of the form of the pulse wave which enters the retinal artery.

The expansile pulse is an expression of systolic and diastolic rise and flow of blood pressure in the retinal arteries. As regards the influence of the intraocular pressure as expansile pulse, even normally it tends to favor the appearance of the pulse: (1) by impeding the outflow of blood from the veins, (2) by the support it gives to the walls of the arteries themselves. The intraocular pressure is a necessary factor in the occurrence of the expansile pulse, even when it is normal. The elevation of the intraocular pressure is capable of producing expansile pulse in the retinal arteries of healthy eyes, but it is equally true that the expansile pulse is as commonly observed, and in the most striking form occurs in cases where the ocular tension bears a normal relation to mean blood pressure, in which there is an abnormally large interval between systolic and diastolic blood pressure. This is the outstanding factor in the mechanism of the expansile pulse in the retinal arteries. Therefore, in explaining the expansile pulse, the relation between three things must be considered, namely, intraocular pressure and systolic and diastolic pressure of the retinal arteries. It may be assumed, however, that within certain limits intraocular pressure varies along with the mean blood pressure, and will have a fairly constant relation to the pressure in the retinal arteries and veins, and intraocular pressure must be lower than diastolic pressure with the finger to cause intermittent emptying of the ends of the arteries, and it must be only a little lower than blood pressure in the retinal veins, since very slight pressure with the finger is required to empty the vein ends. A certain increase of intraocular pressure by the finger will in favorable cases produce expansile pulsation of the retinal arteries, while a still greater pressure will produce the collapsing pulse, which corresponds to the point of maximum oscillation of the vessel wall, indicating that intraocular pressure is then equal to the diastolic pressure in the retinal arteries. In any normal individual the intraocular pressure is so much below diastolic pressure of the artery that the oscillation of the wall is slight and invisible. When any change occurs by which the intraocular pressure is approximated to the diastolic pressure in the artery, the relation of extra- and endovascular pressure will be such as to cause a distinct oscillation of the arterial wall. This state of affairs may be brought about in the eye, either (1) by raising intraocular pressure to meet the diastolic endovascular pressure, or (2) by bringing down the diastolic pressure to meet the intraocular pressure. The first case represents the state of affairs in glaucoma, in which the intraocular pressure rises independently of retinal blood pressure until it may readily reach a point near to the diastolic pressure in the artery. It is also the condition produced temporarily by pressure with the finger just short of that needed to produce the collapsing pulse. It can be readily understood that in either of these cases if the "pulse pressure" in the central artery is small, even such an approximation of the pressures may be unable to elicit a visible expansile pulse. This will explain why the expansile pulse is seldom seen in glaucoma, and not easy to observe in the finger pressure experiment. Since intraocular pressure bears a fairly constant ratio to the mean arterial pressure, then if the former remains normal the approximation of intraocular pressure and diastolic pressure in the artery will necessitate an increase of pulse pressure, that is, an increase of the interval between systolic and diastolic pressure in the artery. It will be observed that this is what occurs in cases where the expansile pulse is most typically seen, namely, in cases of aortic regurgitation in which a pulse wave is found even in the finest divisions of the arteries. The two conditions which must be fulfilled for the production of the expansile pulse are (a) extravascular pressure nearly equal to diastolic endovascular pressure, and (b) a high range of pressure inside the artery.

Certain facts tend to show that the intraocular pressure plays a rôle in the causation of the expansile and collapsing forms of the retinal pulse as well as in the pressure pulse, and the different forms of the pulse are more closely related to one another than is generally supposed. By varying degrees of finger pressure an expansile pulse passing into a typical collapsing pulse has been produced. In a case of glaucoma also a phenomena linking together these two forms of pulse has been observed. Expansile pulse, present both on the disc and beyond it, was readily converted to typical collapsing pulse, within the area of the disc, and increased in distinctness beyond the disc margin, by slight pressure on the eye with the finger. In cases of aortic regurgitation the same phenomena may be elicited. In one case pressure pulse was found without artificial pressure. Locomotor pulse, observed in an extremely anemic girl, was suddenly converted into collapsing pulse when a fainting fit occurred, the fall of blood pressure being so sudden that it was not at once accompanied by a fall in intraocular pressure.

These observations are sufficient to show that while in the majority of cases of the pressure pulse high intraocular pressure is the preponderating factor, and in the typical expansile pulse the form of the pulse wave is of greatest importance, still the two forms of the pulse are not entirely separate phenomena, but have this in common: that the intraocular pressure plays a part in their production, and that in both of them the intraocular pressure is equal, or nearly equal, to diastolic blood pressure in the retinal arteries.

The mechanism of the capillary pulse resembles closely the well known capillary pulse seen under the finger nail in cases of aortic regurgitation, except that on the disc it is usually a spontaneous phenomenon. It is probable that under physiologic conditions the circulation in the capillaries of the retina and disc is pulsatory as regards pressure and velocity, but without causing expansion and contraction of caliber. But if the pulse wave is modified as we have it in aortic regurgitation, the conditions are at once established for the conversion of this into an actual expansion and contraction of the capillaries, showing itself as the visible capillary pulse.

The capillary pulse and the three forms of arterial pulse are related to each other through their dependence on a common mechanism which comprises two factors, viz., the intraocular pressure, and the blood pressure within the retinal arteries. In the case of the locomotor pulse the influence of the first is at a minimum, while in the best marked examples the second is pathologic, in the sense that the range between systolic and diastolic pressure is abnormally great. In the case of the expansile pulse intraocular pressure may be abnormal, as in glaucoma and the finger pressure experiments, but to a far greater extent this pulse also depends on the oscillation of the blood pressure, e. g., as in aortic regurgitation. In the case of a collapsing pulse intraocular pressure may be pathologic, with blood pressure normal (glaucoma and pressure experiments); or with abnormal intraocular pressure, endovascular pressure may be abnormal (syncope and cardiac disease with dropped beats), or both factors may be pathologic (experimental pressure in aortic cases). The most typical of these possibilities is, of course, glaucoma. The conditions associated with the capillary pulse resemble most closely those of the expansile pulse, but the capillary pulse may sometimes be produced experimentally by application of pressure in cases of aortic regurgitation or even in normal eyes.

With a view to arrive at a conclusion as to the diagnostic and prognostic significance of the arterial pulse, notes were kept on (1) 319 patients in the medical wards of a general hospital, and (2) 100 unselected refraction cases, presumably healthy subjects. Among the latter locomotor pulse alone was found in 33 per cent., the expansile pulse, along with the locomotor, in 3 per cent., the pressure pulse and capillary pulse not at all; an arterial pulse of some kind in 36 per cent.

Analysis of the medical cases in group 1 gives the following results: (a) The locomotor pulse alone was present in 75 = 23.5 per cent. (b) The expansile pulse alone was present in 32 = 10.03 per cent. (c) The capillary pulse alone was present in 13 = 4.07 per cent. (d) The pressure pulse alone was present in 1 = 0.03 per cent.

From these figures and the writer's general experience the conclusion is reached that a slight displacement pulse is seen, if carefully looked for, in more than a third of healthy individuals, that some diseases have the effect of suppressing the pulse or rendering it less distinct, while others render it abnormally distinct and in many cases even produce in addition the expansile pulse and capillary pulse.

An effort was made to determine the *diseases that favor the occurrence of the pathologic pulse* and the circulatory conditions in virtue of which they do so.

(a) The locomotor pulse—It occurs that two pathologic conditions, viz., anemia and aortic regurgitation, are peculiarly liable to be accompanied by a pronounced and probably pathologic locomotor pulse.

Anemia is of secondary importance, since the more fully developed phenomena of the expansile pulse, pressure, and capillary pulses. are to a much greater extent conditioned by the presence of the aortic regurgitation.

The condition present in a typical aortic regurgitation explains why it is the condition par excellence in which arterial pulse is found in the retina. The incompetence of the valve allows more or less of the blood expelled at systole to regurgitate into the ventricle during diastole, hypertrophy and dilatation of the left ventricle occur, and hence at each systole an abnormally large volume of blood is forcibly thrown out into the aorta, while at diastole the volume of blood in the aorta abruptly falls through failure of the valves to prevent its return. This results in the transmission into the arteries of a pulse wave which is of large amplitude, abrupt in its rise and fall and of short duration. The great variations of pressure to which the arteries are subjected by these abnormal conditions make is impossible for them to maintain their normal tonicity, they become more lax, and this not only renders more manifest the abnormal character of the pulse wave, but allows it to be propagated to a greater distance than under normal conditions, even to the capillaries.

Cases which show distinct expansile or capillary pulse in the retina, not suffering from aortic incompetence, do so only in so far as they present circulatory conditions resembling those described above. See, also, **Heart disease.**

Arterial pulse in the retina seems to be more pronounced in exophthalmic goiter than in healthy individuals.

No reliable statement can be made as to the frequency in the various forms of glaucoma. The phenomenon has been described most frequently in cases of subacute or non-inflammatory types. The characteristic pulse in these cases is, of course, ''pressure'' pulse, but this is not by any means always present.

Summary.—1. The locomotor pulse in its slighter form may be considered physiologic or at least not pathologic. Excitement is probably responsible for its temporary appearance in some cases. The only forms of illness which appear to favor the occurrence of a locomotor pulse, apart from the pronounced degrees of it associated with the expansile pulse, are anemia and perhaps certain forms of debilitating disease, such as diarrhea and malignant disease; and the latter probably act in the same way as anemia, namely, through loss of vascular tone. In its most pronounced form the locomotor pulse has the same significance as the expansile pulse.

2. The expansile pulse has also been observed in healthy persons, but not nearly so frequently as the locomotor pulse. In the great majority of cases it is associated with incompetence of the aortic valves, and apart from this it seems to occur only when the circulatory conditions characteristic of aortic incompetence are more or less in evidence.

When a well marked expansile pulse is present it is practically always accompanied by an equally well marked locomotor pulse.

3. About one-half of the cases which showed the expansile pulse had at the same time a capillary pulse on the disc, and, as the latter is rarely seen apart from aortic regurgitation, its significance is similar to that of the expansile pulse.

Pulver. (G.) Powder.

Pulverkörner. (G.) Powder grains.

Pulvinar. The posterior eminence, or tubercle, of the optic thalamus.

Pumice stone. Called by the Greeks "Cisseris," and by the Romans "Pumex." It was burnt and reduced to a powder, then employed, by the ancient Greeks and Romans, for ulcers of the cornea. It was thought to hasten cicatrization.—(T. H. S.)

Pumpkin. In ancient Greco-Roman times, a pumpkin poultice was often employed as a remedy in various diseases of the eye. It still enjoys a certain reputation for these affections in the rural districts of the United States.—(T. H. S.)

Puncta lachrymalia. See p. 351, Vol. I of this *Encyclopedia*.

Puncta lacrimalia, Anomalies and diseases of. See p. 6919, Vol. IX of this *Encyclopedia*.

Punctate cataract. See p. 1573, Vol. III of this *Encyclopedia*.

Punctiform depiction. Freedom from astigmatic distortion or aberration in all parts or points of the field of regard. See **Isokrystar lenses.**

Punctograph. An instrument for the radiographic localization of foreign bodies in the tissues.

Punctum cæcum. The blind spot. See p. 1205, Vol. II of this *Encyclopedia*.

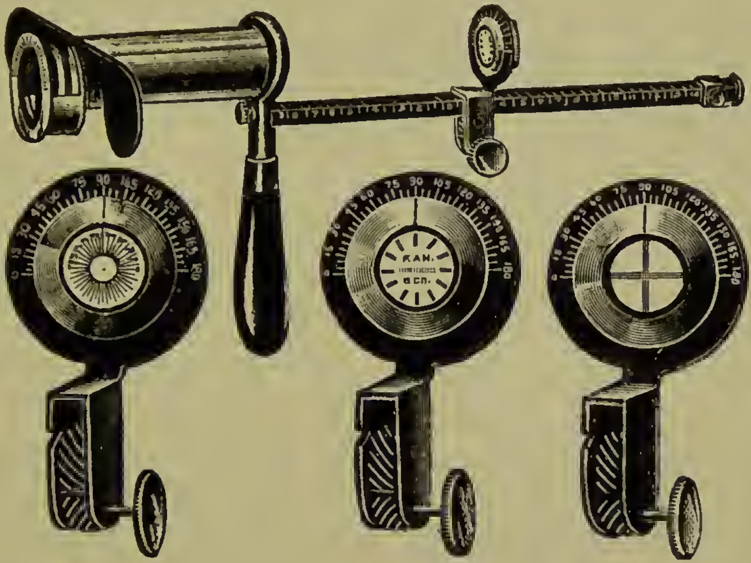
Punctumeter. A (patented) instrument devised for measuring accommodation and refraction. See **Examination of the eye.**

The "improved" punctumeter is a patented device that enables an operator to obtain more or less accurate results. See the cut.

With the rotable target holder and targets it is possible to measure the range or amplitude of accommodation quickly; the amount of this power, to ¼ of a diopter, being read from the scales on the instrument.

The targets for measuring astigmatic errors consist of parallel hair lines which may be made to lie in the principal meridians of the eye. These lines being at right angles to each other and made to rotate, may be used only in the meridians of greatest and least refraction. With such lines occupying such positions it is possible to obtain both the remote and the proximal points.

The principal meridians are readily found with the new astigmatic chart, and when they are located the eyes are easily and quickly measured. Myopia, hyperopia, presbyopia, astigmatism and accommodations may all be measured with this instrument. Latent hyperopia or spasm of accommodation may also be detected and the amount estimated.



The "Improved" Punctumeter.

The targets and holder may be used on any instrument.

Punctum luteum. MACULA LUTEA. The central yellow spot of the retina. See p. 7572, Vol. X, of this *Encyclopedia.*

Punctum, Misplaced. See **Congenital anomalies.** A case in which the lower punctum was located on the upper surface of the lid about 1 mm. from the lid edge and leading directly into the canaliculus is reported by Clark W. Hawley (*Prac. Med. Series;* Eye, p. 81, 1912). The lid was otherwise normal and the condition was the same on both eyes. The epiphora, resulting from the misplaced punctum was relieved by an incision from the punctum on to the inner surface of the lid and toward the inner canthus.

Punctum proximum. The near point. The nearest position to the eye at which a fine object can be seen sharply and without blurring. See p. 8290, Vol. XI, and p. 329, Vol. I, of this *Encyclopedia.*

Punctum remotum. See **Far point,** p. 5164, Vol. VII of this *Encyclopedia.*

Puncture, Brain. The value of this procedure for the relief of the intracranial pressure from brain tumor, meningitic deposits, cysts, etc., is often very great. Our knowledge of the technic and clinical value of brain puncture dates from the publication of the thorough experimental and clinical study of Neisser and Pollock (*Mitth. a. d. Grenzg. d. Med. u. Chir.*, Vol. 13, p. 807, 1904), yet Middledorpf (*Günzburg's Ztschr. f. Klin. Med.*, Breslau, 1856, Vol. 7), in 1856, had suggested the procedure on the basis of experimental evidence. Maas not long afterwards insisted on its use as a preliminary step in the operative treatment of brain abscess.

In this country Souchon (*New Orleans Med. and Surg. Jour.*, 1889), in 1889, developed a technic from animal experiments. Schmidt (*Arch. f. Klin. Chir.*, Vol. 45, 1893, p. 586), four years later, pointed out the surgical possibilities of the procedure, particularly in connection with the treatment of abscesses of otogenic origin.

Payr (*Centrlbl. f. Chir.*, 1896, No. 31, Vol. 22, p. 737) a little later extended the technic to include the harpooning of brain specimens for histological examination, a procedure which has found little favor elsewhere, and justly so, on account of the very considerable dangers and relatively small benefits connected with it.

The Kocher (*Centrlbl. f. Chir.*, 1899, No. 22, p. 643) clinic, in 1899, already had a well-developed technic, which was published by Albert Kocher, and does not differ particularly from that at present in use.

One year before Neisser and Pollock published their work, Nicholas Senn published a case of internal hydrocephalus, which he had treated by connecting the subcutaneous tissue of the scalp with the ventricle by means of a thin rubber drain, using at the same time elastic compression of the skull. This method of ventricle drainage was first used by G. A. Sutherland and Watson Cheyne (who used folded lengths of catgut instead of rubber), and later, though published earlier, by Henle, who used a gold tube.

Since the appearance of the paper of Neisser and Pollock, the method has been tried extensively and has come to occupy a permanent if rather limited field of surgical usefulness.

B. Pfeifer has reported the experience of Wernicke's clinic at Halle, and F. Krause has reported his experience on a still larger material.

For diagnostic purposes brain puncture is at present done chiefly after the dura has been exposed by cranial resection, so that possible hemorrhage may be controlled and purulent fluid be walled off from the meningeal spaces. It is generally employed: (1) to locate subdural and epidural hematomata; (2) to locate collections of pus; (3) to locate cysts of various origins; (4) to locate and determine the character of brain tumors—a dangerous and not very reliable procedure, but still used by F. Krause.

For purposes of treatment it is used for (1) temporary and permanent drainage of the ventricles in internal hydrocephalus, acute and chronic, whatever the origin; (2) evacuation of pus and blood; (3) evacuation of fluid from meningeal spaces and lateral ventricles to diminish pressure before decompression or exploratory operations.

Dangers of brain puncture. 1. The chief danger is from *hemorrhage,* which is naturally very much less when the puncture is done in connection with a resection of the cranium, so that large veins can be avoided and any bleeding promptly seen and checked.

In the use of the puncture through a small trephine opening by the method of Neisser and Pollock, the chief danger is from injury to the *pial veins* by the point of the exploratory needle. Though normally small, in diseased conditions they are often greatly dilated and the walls are at all times very fragile and delicate. The dural veins are injured less easily, but may give rise to very severe hemorrhage at times. The branches of the middle meningeal artery may be injured during the trephining, but they are more easily seen and the hemorrhage controlled by ligation.

Vascular tumors on the surface and in the tissue of the brain are still more dangerous to puncture; *e. g.,* angiomata, angiosarcomata, etc., may exist, which may easily give rise to fatal and unrecognized hemorrhage.

2. *Septic infection* is rarely likely to be carried in from without, but may easily infect the meninges from a punctured abscess if the Neisser and Pollock puncture is done without walling off the meningeal space.

3. *Tumor infection* may easily be carried into the healthy parts of the brain by the exploring needle when the tumor lies superficially and the needle, as often happens, is inserted through and beyond it.

4. *Focal symptoms* from destruction of nerve centers are avoided by not putting in the needle too deeply (four inches is the limit in any direction, and five to six centimeters is usually far enough).

Pons, medulla and basal ganglia lie so deeply that there is rarely danger of striking them. Puncture in the motor area may have disagreeable after-effects, as in a case of F. Krause's, which was followed by temporary arm paralysis and severe general prostration and shock.

5. *Sudden collapse* from diminution of intravenous pressure may occur with the larger collections of blood and pus, but is especially apt to occur in the evacuation of an internal hydrocephalus. If this happens the head is lowered and the veins filled with salt solution and adrenalin. The best means of preventing this complication is to slowly evacuate the fluid.

6. Acute and fatal edema of the brain associated with great in-

crease of intracranial pressure occasionally follows puncture of the ventricles. Repeated emptying of the lateral ventricles and stimulation restored the patient.

Technic and location of brain punctures. There are a few obvious rules to be observed which make the location of the puncture a relatively simple performance. 1. Avoid blood vessels. (a) Punctures are not made near the mid-line nor near any of the venous sinuses, for fear of wounding the larger blood vessels as well as the sinuses themselves (*i. e.,* transverse sinus, longitudinal sinus, sigmoid sinus, occipital sinus, etc.). (b) Also avoid the neighborhood of the larger blood vessels, particularly the middle meningeal artery. (c) In general, avoid puncturing through a small opening because of the difficulty of seeing what one is puncturing and of recognizing hemorrhage promptly, when it occurs. (d) Do not puncture through a sulcus, but through the convexity of a convolution, because in the sulci run the vessels.

2. Explore for pus through the lowest possible openings, thus securing the best possible drainage, if pus be reached.

3. Tap hematomata from the point of visible injury (unless there are other focal symptoms and the visible injury is slight).

For the technic of simple puncture, see **Brain puncture.**—(A. E. H.)

Puncture, Callosal. Balkenstich. See, also, **Puncture, Brain**; as well as p. 3793, Vol. V of this *Encyclopedia.*

Trephining and draining of the lateral ventricle.

This form of cerebral decompression (and five cases recorded) is described by Kaelin-Benziger (*Ophthalmic Year-Book,* p. 262, 1913).

The results of callosal puncture in hydrocephalus and other intracranial pressure conditions was compared with the results of palliative trepanation (figures of von Hippel) by Muskens, who greatly favors the former measure. He thought it rather peculiar that the condemnation by the neurologists of lumbar puncture as a dangerous proceeding had not affected the ophthalmological mode of procedure. However, callosum puncture was sure to cause a retrogression of a choked disk and he voiced the belief that any choked disk of three or more diopters that existed for more than two weeks without involvement of vision, should undergo a callosum puncture. If the condition is one of cerebral edema, either acute or subacute, which may last for a long time, the operation is more than ever indicated. The writer regards a bilateral choked disk, occurring with tumor of the brain, as a distinct indication for this decompressive operation, even if the visual function of one or both eyes be still normal. The longer the pressure on the nerve has continued, the poorer are the prospects for retention of vision or for improvement after operation. Since solid tumors are often complicated by hydrops of the ventricle, trephining must often be followed up by temporary extracranial drainage. In the author's cases the cerebral symptoms and the choked disk disappeared in from twenty-four hours to two weeks after the operation.

Hessberg also reports five cases of hydrocephalus and two of brain tumor for which puncture of the corpus callosum was done. He concludes that the operation is a comparatively simple one for the relief of intracranial pressure. The decided lowering of tension showed itself objectively by decrease of exophthalmos, improvement in the visual field, and regression of the nerve swelling; and subjectively by disappearance of headache and improvement in the general condition.

Puncture points, Cranial. See p. 1270, Vol. II of this *Encyclopedia.*

Puncture, Spinal. See, also, **Lumbar puncture**, p. 7545, Vol. X of this *Encyclopedia.*

Although the chemical and physical characters of the spinal fluid in health and disease, its origin and movements, have been studied in animals and man since Cotungo's time (1769), it is only of recent years (Quincke, 1891) that we have been able to use it for diagnosis and therapy.

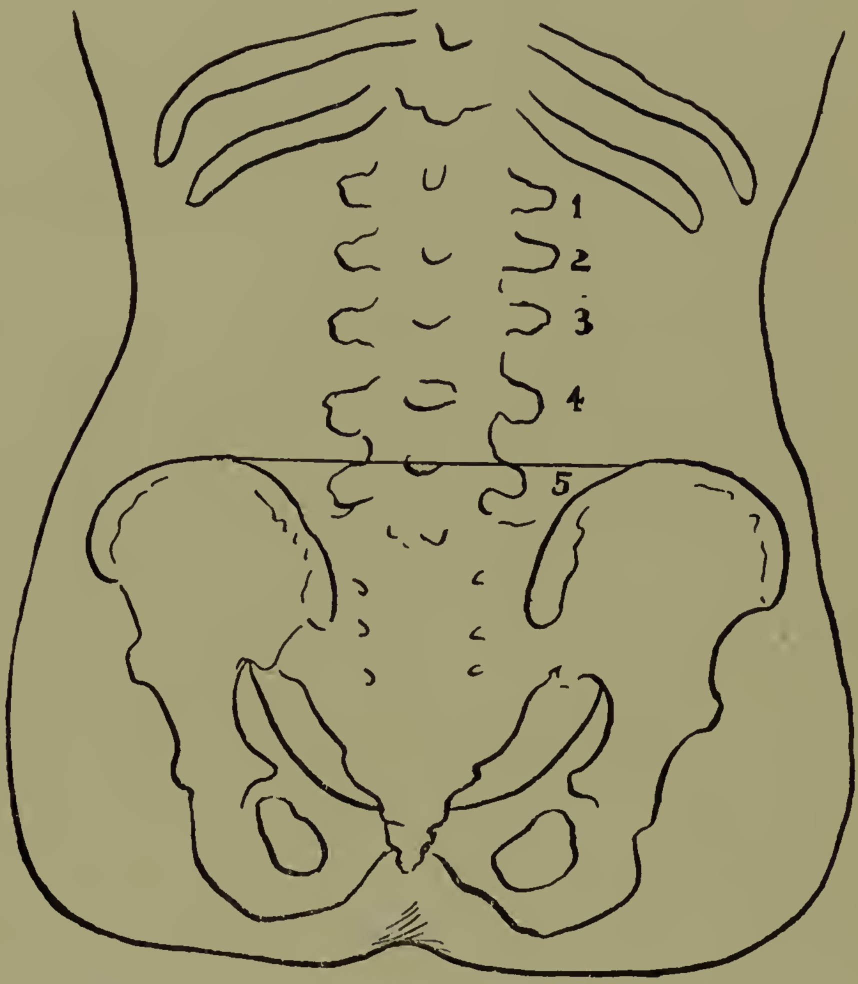
The chief indication for the performance of lumbar puncture occurring in connection with eye symptoms is meningitis in its various forms. Here the puncture is an invaluable diagnostic aid and likewise an important aid to therapy. All other indications are very infrequent when compared with meningitis, the presence of which can be diagnosed and its varieties differentiated by examination of the spinal fluid obtained.

Drainage of pus and irrigation to a slight extent may be practised by means of the puncture, but much more important, from a therapeutic standpoint, is the injection of the Flexner serum into the subarachnoid space in cases of epidemic meningitis.

Intrameningeal hemorrhage may also be diagnosed by the puncture, but always has an element of doubt, inasmuch as a vessel wounded by the needle may lead to a similar finding, although in the latter instance the blood, as a rule, is redder than in the former, and less diffusely distributed through the fluid, being usually more marked in the first few drops than in the last.

Increased intracranial pressure, whether due to tumor cerebri, hydrocephalus, hemorrhage or meningitis, may often be diagnosed by the increased pressure of the spinal fluid, which, normally flowing 60 m. per minute from the needle, may fairly spurt out when pressure is high. The normal pressure is 5 to 7½ mm. of mercury, or 60 to 100 mm. of water, which may be increased under pathological conditions to 15 to 60 mm. of mercury, or 200 to 800 mm. of water.

In the last few years the cytological, chemical and biochemical examinations of the spinal fluid, as obtained by spinal puncture, have assumed great importance in the diagnosis of syphilis and the parasyphilides.

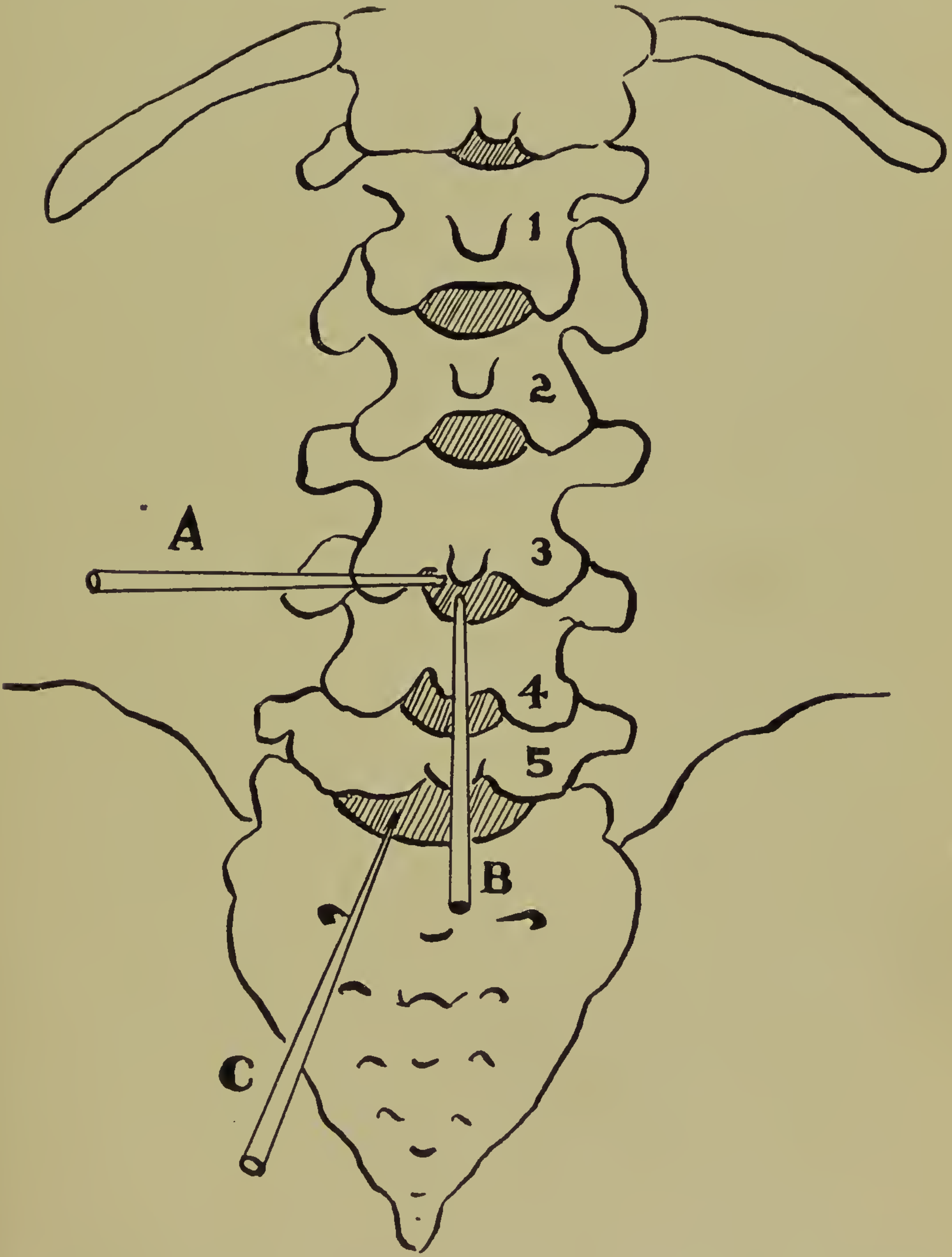


Spinal Puncture. Relations between the Lumbar Spines and Crests of the Ilia shown by the Transverse Line.

The mononuclear leucocytosis, excessive presence of globulin and the Wassermann and Noguchi tests have made the differentiation of the parasyphilides from syphilis, and both from non-syphilitic affections, much more accurate.

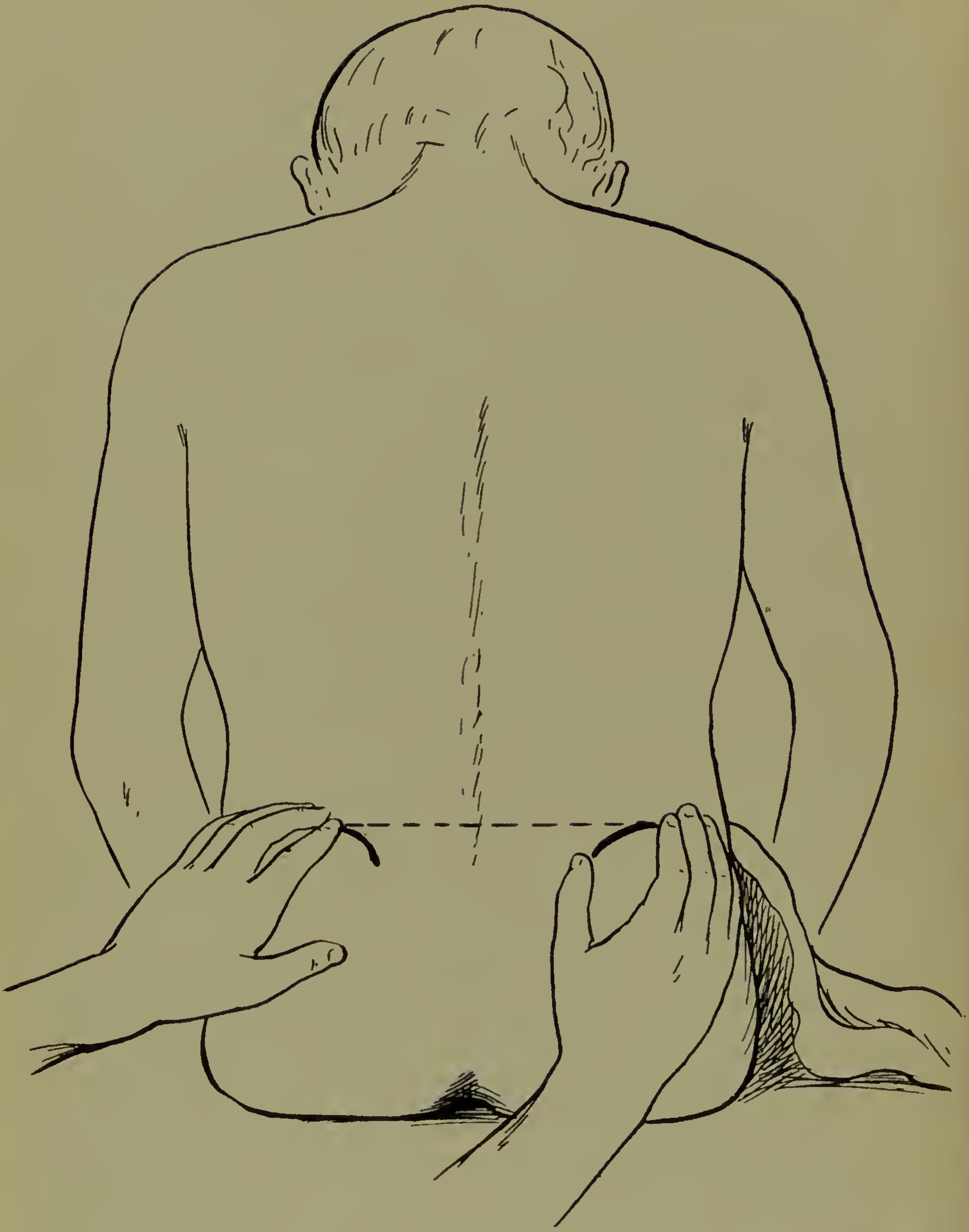
Other less important indications are derived from the presence in the spinal fluid of an excess of urea in uremia, and the presence of cholesterin and cholin in cases of various degenerative processes of the central nervous system.

The application of therapy by means of spinal puncture is always associated with danger to life. The evacuation of fluid, whether it be



Method of Puncture for Spinal Drainage. A, Quincke's site; B, Marfan's site; C, Chipault's site.

normal, purulent or hemorrhagic, always entails some risk of allowing the medulla to sink into the foramen magnum and become incarcerated



Topographical Relations for Spinal Puncture, according to Tuffier. The line joining the crests of the ilia passes directly over the spinous process of the fourth lumbar vertebra. The needle is inserted just above the spinus process to reach the third interspace, or below it to reach the fourth.

there, to the detriment of its vascular supply. The central canal and subarachnoid space may also become blocked, thus leading to an acute hydrocephalus or pyocephalus, as the case may be.

To avoid this danger only a small amount of fluid, usually 20 to 40 c.c., should be evacuated at one time, and the patient should be placed in the lateral, and not in the sitting position during the procedure.

The evacuation of the pus in meningitis by spinal puncture is not of much therapeutic value. Puncture is of importance here chiefly because it enables us to introduce Flexner's antimeningococcic serum directly into the subarachnoid space. For this serum injection the needle is introduced in the ordinary way, a few drops of fluid allowed to escape, and then the serum is injected through the needle—20 to 100 c.c. The procedure may be repeated every day until convalescence begins. The unanimous enthusiasm of clinicians over the whole world proves the great value of this procedure. By it the mortality of the scourge has been reduced from 75 to 25 per cent. wherever it has been used. It is a great discovery of which America may well be as proud as France is of Behring's serum.

The treatment of increased intracranial tension by lumbar puncture had considerable vogue to within the last few years. Cushing (*Jour. A. M. A.,* Jan. 16, 1909, p. 184) has laid such emphasis, however, on the danger of medullary hernia into the foramen magnum in such cases, and there have been so many such cases reported, that it would seem hardly justifiable at the present writing to adopt such a procedure in view of the excellent results now obtained by cranial procedures.

Technic of spinal puncture. Quincke recommended that the puncture be made between the second and third, or third and fourth, vertebræ. The writer nearly always uses the latter location because of the readiness with which it is found by drawing a line between the crests of the ilia. This line passes over the fourth lumbar spinous process; just above it insert the needle.

Many clinicians recommend that the puncture be made in the mid-line, but the writer prefers, however, to enter the needle one-half to one centimeter to one side of the median line, as originally proposed by Quincke, in order to avoid going through the tough ligamentum interspinosum.

The needle can also be inserted between the fourth and fifth vertebræ or between the fifth vertebræ and the sacrum, and it is not improbable that in an occasional instance pathological constituents of the spinal fluid, which have settled to the lowermost part of the subarachnoid space, may be found here, though missed on puncture at the usual location. Such an occurrence, however, is certainly very rare and is not a practical consideration.

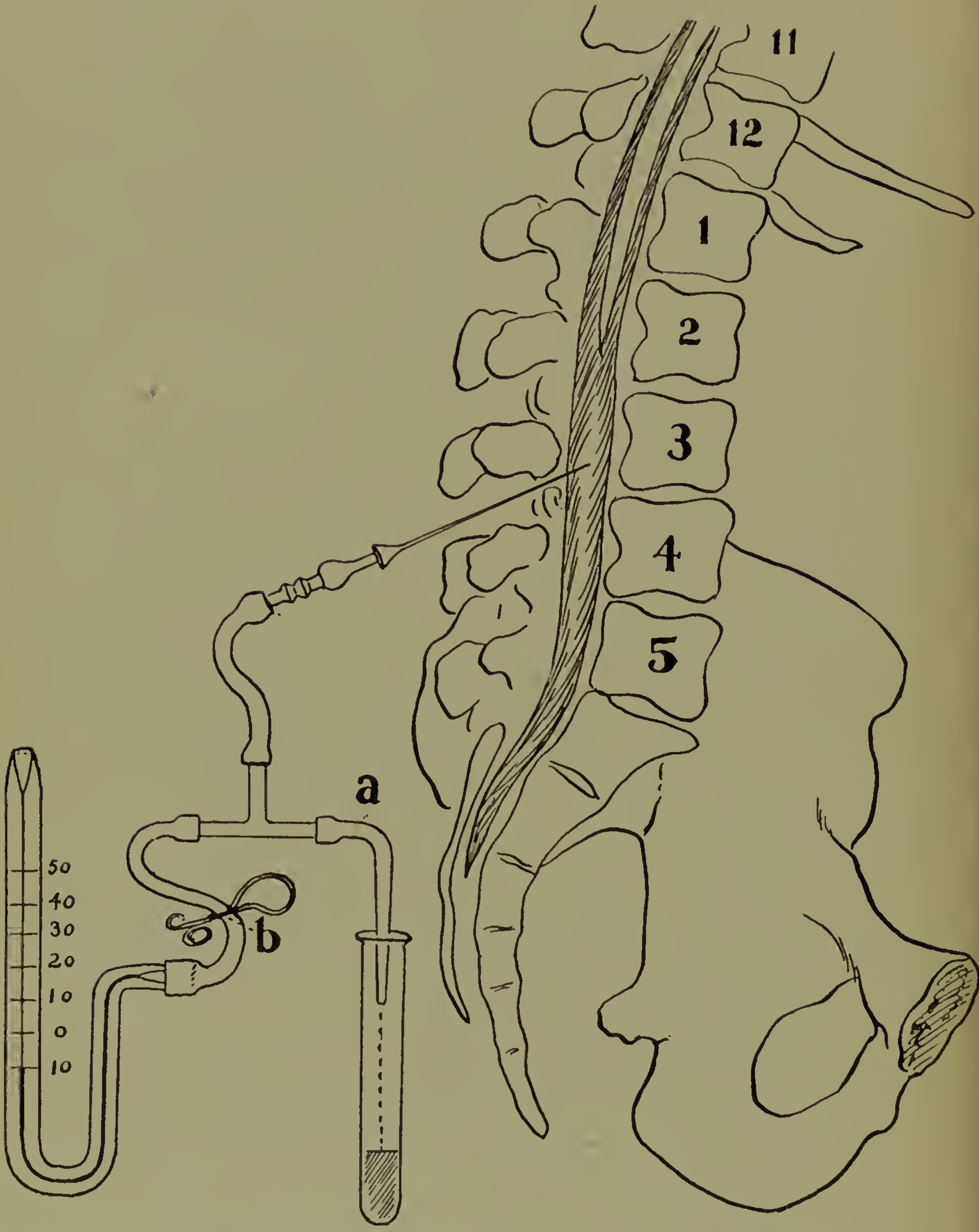


Diagram of Lumbar Puncture. T-shaped glass tube for combined drainage and estimation of the pressure of the spinal fluid.

The needle, once entered in the skin just outside the mid-line, is pushed inwards, slightly upwards—in adults, horizontally in children, and medianwards. The dura is reached at a depth of four to six centimeters in adults, or of two centimeters in a two-year-old child. If the tip of the needle engages bone at the first attempt, withdraw a little, change the direction and try again.

The position of the patient during the puncture should be the lateral recumbent, with the spinal column flexed to a maximum, in order to enlarge the posterior intervertebral aperture.

The recumbent posture is preferred because there is less danger of cerebral vascular disturbances or hernia of the medulla into the foramen magnum in the lying position.

When the spinal fluid runs out it is caught in a sterile test tube. The rate of flow and incidentally the pressure of the spinal fluid is determined by counting the drops as they flow from the end of the needle. The normal rate of flow is about sixty drops per minute. More than this number means increased spinal and consequently increased intracranial tension. Occasionally, when the pressure is very high, the fluid may flow in a continuous stream instead of in drops. A number of drops less than sixty per minute indicates either hypotension or partial plugging of the needle.

The needle should be withdrawn as soon as the pressure falls to normal. As a rule, it is safe to stop somewhat before normal, in view of the ever-present danger of hernia of the medulla into the foramen magnum.

It seems hardly necessary to state that the needles should be sterilized by boiling in one per cent. sodium carbonate solution, and the skin sterilized by some one of the accepted methods. Simple disinfection with 95 per cent. alcohol or painting with tincture of iodine, according to Grossich, is enough.

An anesthetic of any sort is usually not necessary, though it may be desirable at times to anesthetize the skin with the ethyl chloride spray.

The examination of the spinal fluid is more appropriately to be discussed in one of the standard textbooks on laboratory diagnosis.—(A. E. H.)

Puniceous. Of a purplish-red color.

Punktal. An ophthalmic lens in which the astigmatism for oblique pencils of rays has been corrected over the entire field covered by a visual angle of 60°. This lens is the result of scientific investigations by Moritz von Rohr, physicist of the Carl Zeiss works, Jena, who based his calculations upon the theory that a curve bearing a definite relation over an arc of 60° to the center of rotation of the eye, at a given distance of 25 mm., and corrected for each power independently, would eliminate the astigmatism found to be so objectionable in the older forms of lenses. Measurement of its dioptral power is based on vertex-dioptrics. See *Vertex refraction* under **Lenses and prisms, Ophthalmic,** p. 7340, Vol. X of this *Encyclopedia.* —(C. F. P.)

Punktförmiger Staar. (G.) Punctate cataract.

Punti della glandola lagrimale. (It.) Mouths of the lachrymal glands.

Punto cieco di Mariotte. (It.) Blind spot.

Pupil. The hole in the center of the iris.

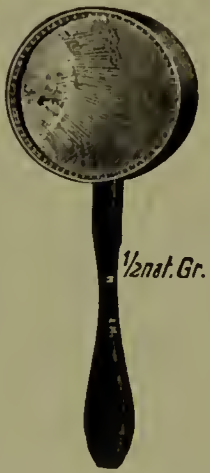
The pupil appears commonly as a black spot in the middle of the colored part of the eye, this appearance being due to the darkness of the posterior part of the globe. It varies in size, in man, according to the stimulation of light and the power of accommodation. It is readily influenced by certain drugs, by certain disease conditions and by traumatism. For a complete description of the pupil under many varying conditions, see **Pupil in health and disease** very shortly following in this volume.

Pupil, Argyll Robertson. One that is responsive to accommodative effort but not to light. See p. 567, Vol. I of this *Encyclopedia,* also under **Pupil in health and disease** in this volume.

Pupil, Artificial. See p. 634, Vol. I, as well as p. 6578, Vol. IX of this *Encyclopedia.*

Pupilary. PUPILLARY. Pertaining to the pupil of the eye.

Pupilantoscope. This little instrument was devised by Munch (*Klin. Monatsbl. f. Augenheilk.,* June, 1912) for the purpose of critically examining the ever varying changes in one's own pupil and iris, under the influences of light and accommodative effort. It is provided with a magnifying, convex lens (mounted on a handle) set in



Munch's Pupilantoscope.

front of a concave mirror. The examination of the movements in and of the sphincter pupillæ, as well as of other portions of the iris is carried on in a dark room under a weak, lateral, focal illumination.

Pupil, Bounding. A pupil which shows alternating dilatation and contraction. See **Hippus.**

Pupil, Bumke's. Dilatation of the pupil following a psychic stimulus. It does not occur in dementia præcox.

Pupil, Cat's eye. Slit pupil. One with a narrow, vertical aperture. See p. 2855, Vol. IV of this *Encyclopedia.* See, also, under the heading **Pupil in health and disease** shortly following hereafter, with illustrations.

Pupil, False. The so-called pseudopupil of invertebrate eyes. See **False pupil.**

Pupil, Hutchinson's. A unilateral mydriasis.

Pupil in general anesthesia. See **Ether,** p. 4526, Vol. VI; also **Chloroform,** p. 2065, Vol. III of this *Encyclopedia.* To the matter found there it may be added, regarding the significance of the pupillary reaction during general anesthesia, that the loss of the corneal reflex has been used as an index of the degree of narcosis for many years, but Northrop (*Northwest Medicine,* April, 1906) believes it to be unscientific and useless, and its application a score of times during a single operation positively barbarous. While there is no one signal that is an infallible guide, the pupillary reaction is the nearest approach to it. A rapidly dilating pupil means danger, and a fixed, dilated pupil extreme danger. A contracted, immobile pupil usually means safe surgical anesthesia; oscillation indicates diminishing narcosis. The pupil is sometimes modified by the manipulation of excessively sensitive tissue or a sudden change of the patient's position. In the primary stage of ether anesthesia the pupils generally dilate but react well to light. As ether is added, the pupil contracts more and more, and reacts sluggishly to light, finally becoming immobile, having reached the "mid-point" (Hartley) of safe surgical anesthesia. If the anesthetic be pushed, the pupil will dilate and finally cease to react, the cornea becomes insensitive, and danger signs appear, indicating the approach of cardiac or respiratory failure, or both. If the ether be discontinued the patient will begin to react, the pupil gradually going back through the same series of changes reversed, or it may dilate suddenly, reacting to light, and the patient begins to struggle or vomit. In chloroform narcosis the changes are similar, but more rapid, and must be watched for with even more care. A point to be remembered is that the cornea is affected early by chloroform. See, also, **Pupil in health and disease,** *infra.*

P. U. O. Abbreviation for "pyrexia of unknown origin"; an English designation for trench and other forms of undiagnosed fever.

Pupil, The, in health and disease. Pupil, from latin, *pupus,* boy, *pupa,* girl. In a secular sense, it means (1) a youth or maiden who is under instruction. (2) A disciple or follower who believes and teaches what he has been taught.

There seems to be no connection between the above etymology and the anatomical definition— "the normal perforation in the iris" excepting that it is believed to refer to the tiny, child-like image reflected from the cornea corresponding to the location of the pupil. Pupil in an anatomical sense is defined, "The aperture in the iris of the eye for the passage of light."

The following argument assists in establishing the pupil as a feature of the eye worthy of careful consideration.

(1) *Its visibility to the naked eye.* Many ocular structures, especially those directly concerned with the function of sight, are concealed from simple inspection. The pupil and its surrounding iris, located at the bottom of the anterior chamber, afford us an opportunity to observe through the clear cornea and aqueous the behavior of the otherwise concealed mechanism which has its connection with many localities of the brain, spinal cord and general nervous system. Irregularities in contour, position, color, size and behavior are easily noticed and the clinical significance of each is so unvarying and far-reaching that not only ophthalmologists, but physicians, surgeons, neurologists, alienists and others familiar with the normal and abnormal pupil are (assisted by other symptoms) led to detect at once such profound systemic states as uremia, opium poisoning, belladonna poisoning, etc., or such grave cerebral states as apoplexy, tumor, abscess, meningitis, such nervous diseases as multiple sclerosis, paresis, tabes dorsalis, hysteria, as well as such alarming emergency states as shock, fatal syncope, sunstroke, exsanguination, epilepsy, tetanus, strychnine poisoning, hydrophobia, eclampsia and death. Indeed, the last rites of the catholic church are ministered by the priest only when on inspection of the pupil in the presence of other evidences of impending death, it is seen to lose its contracted state and to slowly dilate. Thus, the state and behavior of the pupil is looked upon with concern by all who are familiar with the graver problems which confront the physician and surgeon as well as by the clinician in search of confirmatory evidence to assist in making up a diagnosis of some obscure, incipient, vague or transitory malady affecting the cerebrospinal nervous system. The reason for this is because the pupil is

influenced by many kinds of stimuli and inhibitions acting along various nervous pathways from diverse parts of the body and in response to uniform and definite impulses.

(2) *Its relation to deeper ocular structures.* The pupil is an aperture in the iris. The iris is the anterior segment of the tunica vasculosa, composed of structures partly ectodermal and partly mesodermal in origin, and affords valuable data open to naked eye inspection in cases of diseased states and congenital abnormalities of other parts of the tunica vasculosa which are concealed from direct, unaided inspection (the ciliary body and choroid) and also in states referable to the nervous coat of the eye (the retina).

Owing to its anatomical arrangement and to the fact that its behavior is dependent on the state of the so-called ''pupillary light reflex arc,'' as well as the ''cervical sympathetic pathway,'' it is quite possible for the expert ophthalmologist to examine and test the pupil and decide as to whether blindness is present and if so, whether it is from a primary lesion in the eye itself or secondary to some lesion that exists beyond the eyeball. The picture of the fundus as seen through the pupil by the aid of the ophthalmoscope will, of course, assist greatly in the diagnosis.

(3) *Its reaction to accommodation.* The fact that when the eye ''accommodates'' to produce clear vision at short range the pupil in normal states contracts, affords valuable opportunities for information. The independent innervation of the ciliary muscle on the one hand, and the iris on the other, the cerebral connection or association between the centers controlling ciliary action and those controlling pupillary action, afford a fascinating study in cases where there is inharmonious action between the functions of these correlated anatomical structures: e. g., we may have normal accommodation and paralyzed pupils; we may have paralyzed accommodation and normal pupils; we may have pupils contracted and fixed to light, or pupils dilated and fixed to light but which contract when the accommodation effort is used; or we may have both pupil and accommodation paralyzed or in a cramped or contracted state. Each of these problems has its clinical significance and they all afford interesting and valuable information.

(4) *Its consensual reaction.* There are, as is well known, association fibers in the brain connecting the centers of one hemisphere with those of the other, and hence a stimulus delivered to the pupillary centers on one side is referred across to those on the other side and from these centers to the irides of both eyes causing contraction of the pupils in a harmonious and equal manner. But in certain dis-

eased or abnormal states of one eye causing unilateral blindness we have the interesting phenomenon that the pupils of both eyes will contract when the normal eye is illuminated, but both pupils will remain unaffected when the blind eye is illuminated. From the misbehavior of the pupils in this so-called "consensual pupillary action" useful if not indicative evidence can be deduced.

(5) *Its relation to the spinal cord.* The cilio-spinal centers controlling the dilator muscles of the irides are located rather far down in the spinal cord (at or near the first dorsal vertebra). The cervical sympathetic nerves emanating from these centers finally reach the dilator muscular fibers of the irides and hence it is that useful and valuable information is afforded to the clinician as to the state of health of these centers and of certain columns of the cord in their vicinity. There may be *inveterately contracted* pupils due to paralysis of function of the cervical sympathetic nerves, as seen in tabes dorsalis and other similarly degenerated states of the spinal cord, or from traumatism to the cord in this locality, causing the clinical sign known as "paralytic miosis"; or there may be *dilated* pupils through irritation of these nerves in states of functional irritation or inflammation of the cord, as seen in certain acute toxemic states or in peripheral irritations affecting the splanchnic nerves especially observed in children and expressed in twitchings, spasms, convulsions, etc., causing the clinical sign known as "spastic mydriasis." Moreover, the consideration of the fact that there are association fibers connecting the cilio-spinal center with those in the brain controlling the action of the sphincter pupillæ renders the study of problems arising from interruption of the normal impulses to the pupils along this route from tumors, hydrops, cavitations, areas of degeneration, traumatisms, etc., affecting the cilio-spinal center or the association brain and cord fibers above mentioned, of absorbing interest and great localizing value to the diagnostician.

(6) *Its relation to brain surgery.* There are lesions of the brain, such as are produced by tumor, abscess, hemorrhage, traumatism, etc., located on the convexity, at the base, in the brain substance, the ventricles, the contiguous or boundary structures such as the concavity of the skull bones, and cerebral edema with consequent increased intracranial pressure dependent on focal diseases of the brain in which it is important, in view of possible relief from surgical measures, to determine an accurate localization.

In this class of diseases, the so-called "brain cases," the comparative size and behavior of the pupils studied alone or in connection with optic neuritis, strabismus, nystagmus, hemiplegia, etc., afford information of inestimable value. I have known brain cases where the important question as to localization was finally answered by the group of ocular symptoms aided greatly by the evidence afforded from pupillary behavior.

(7) *Its relation to the dioptric media.* The pupil varies in depth from the cornea at different periods of life, its blackness and clearness depends in a measure at least upon the transparency of the cornea and aqueous humor. Its position anterior to the lens enables forms of lens opacification which exist in the pupil area to be studied in regard to their location, size and shape. Its jet color in ordinary daylight inspection as compared with the glitter and sheen observed in cases of glioma or pseudo-glioma of the retina, its opaque indian-red color as seen in cases of hemorrhages in the anterior part of the vitreous by focal illumination, its slaty color as observed in cases where a recent exudation occupies the anterior part of the vitreous body, or when the retina is floating loose in the vitreous, its gray or dark appearance when the "red reflex test" is employed in cases of vitreous exudation from any cause, its appearance in normal and diseased states when transillumination of the eyeball is employed,—all these and many other findings point out the great value of the pupil when tested and examined in the various ways employed to determine the state of the dioptric media of the eye.

In the preparation of this section it was deemed best to scan the subject in a general way and then to arrange the details in alphabetical order for handy cyclopedic reference. Each point in this introductory résumé may be found fully discussed under its appropriate heading in the main body of this section.

GENERAL CONSIDERATIONS.

The width of the pupils varies in health from infancy to old age and pupils often vary in size normally in the same individual. In infancy the pupils are contracted. In youth and adolescence, dilated. In the middle decades neither contracted nor dilated, while in old age they are contracted.

Why does the normal pupil vary in width throughout life? In the infant born into a world of light where the nervous elements of the retina are stimulated for the first time the common belief is that there is a contraction of the pupil because of nature's effort to shade the retina from glare. But there must be another cause. In the newly-born infant the sensorium is still slumbering. The infant brain and nervous system have not yet begun to receive and convey impressions from the outside world. It takes several months before the child knows anything and when that stage begins, or, in other words when the sensory stimuli reach the brain cortex and traverse the nerves of the body, we find the pupils begin to dilate and the period of youth occurs.

In youth and adolescence the entire sympathetic nervous system is unstable as compared with the adult state; the reflexes are all accentuated; the various parts of the body respond in an exaggerated way to the diverse stimuli and it is during these unstable years when the spinal cord is growing inch by inch, and the nerves supplying the different members of the body are likewise rapidly increasing in size and length, that the sympathetic nerves which supply the dilator muscle of the iris are more active. Another argument is that the pupils in abstracted states of the mind, hypnotic states and dream states, are dilated through psychic influence conveyed to the sphincter of the pupil through the course of the 3rd nerve. In youth and adolescence the child lives in a world of make-believe and imagination, moreover during the early years of life the powers of inhibition are feeble. The dilated pupil of youth may be regarded an expression of this general lack of inhibition.

There is a period of several years called the middle age of life when the pupil is neither contracted nor dilated *ad extrema.* These are the stable years when there is a so-called normal balance expressed in the many functions of the body. In middle life the processes of repair and waste are about evenly balanced. There is no longer increased bodily growth. The internal secretions nicely balance the requirements of the body brought about by increased activity during these years. The mental powers are at their best, the ability to do the world's work is most evident during these years. The pupil is never seen to dilate *ad maximum* in states of health during the middle years of life nor is there contraction of the pupil beyond a certain point, certainly not contracted as in the infant and the aged.

In the aged we find the pupil contracted. The common explanation for this is embraced in the comprehensive term, "hardening of the arteries." In senility the capillary walls are less resilient and since the iris is a vascular membrane, we find it stiffened from vascular sclerosis. Fuchs explains senile miosis by declaring the presence of thickening of connective tissue behind the sphincter. Meller states there is hyaline connective tissue at the border of the pupil in the aged. In any event senile miosis may be regarded as a wise dispensation of nature to compensate, at least in a measure, for the loss of accommodation.

Normal pupils are influenced by the following: (1) Light and shade. (2) Sensory stimuli. (3) Drug influence. (4) Emotions. (5) Bodily disease. (6) Sleep, coma and death. (7) Cerebro-spinal nervous states and diseases. (8) Various other conditions which will be mentioned.

We note that the pupil will contract in the light and expand in darkness. This will be studied later on. We also find the pupil responds to the touch, as it were, for if the skin about the face or neck be irritated, or even if a painful inflamed part of the body like a rheumatic joint be pressed upon, the pupil will dilate.

It is a curious fact that the juices of certain plants contain active principles which have striking effects upon the pupil when their solutions are instilled in the conjunctival sac. One class known as mydriatics causes the pupil to dilate; another class known as myotics causes the pupil to contract. Advantage is taken of the specific action on the pupil incited by these alkaloids in controlling certain diseases of the eye where such action is indicated.

The pupil also responds to emotions of a violent nature, such as anger, grief, passion, etc., psychic states in which we find it dilated. In sleep the pupils are contracted in spite of the fact that during sleep we are in darkness and the eyes are closed, conditions favorable to dilatation. The explanation of this must lie in the fact that in the absence of all stimuli the more powerful muscle of the iris, the sphincter, asserts itself and the tone of this muscle permits the contraction. In death the pupil dilates but not *ad maximum.* Among the cerebro-spinal nervous diseases we find interesting behavior on the part of the pupil. In tabes we find it contracted sometimes to a pinpoint, whereas, in epilepsy and convulsions we find it dilated. Between these extremes there are many irregular and sometimes striking conditions of the pupil which aid greatly in fixing the diagnosis. But valuable as the pupil is from a clinical sense there is no single disease of the body which presents pathognomonic pupillary signs.

The *color of the pupil* varies in different periods of life; in childhood and adolescence it is a luminous black; in middle age it appears slightly dull-black or gray-black, while in old age it appears gray. In youth the brightness is due to the clear media. In middle age the loss of brightness is due to the presence of a nucleus in the lens, while in old age the pupil appears gray because this sclerosis of the lens finds its greatest expression, being more or less complete. The cornea too lacks its pristine brilliancy in old age. The differences in the color of the pupil which we note in health at different stages of life are therefore due to interference phenomena.

Anatomy of the pupil. There are two opposing muscles in the iris. One, the sphincter pupillæ, is situated in the tissue of the iris near the margin of the pupil. It is the muscle which produces contraction of the pupil. The other, the dilator pupillæ, is composed of radiating strands which have their origin at the root of the iris and their insertion in the sphincter in which its fibers blend. When the radiating fibers act, granting that the sphincter is relaxed, the pupil expands, for its margin is drawn away from the center by these contracting, radiating fibers. This double-acting muscular apparatus is under the control of, and is directly answerable to, impulses received through different nerve fibers.

The sphincter muscle is composed of interlacing, non-striated, involuntary muscular fibers. The dilator muscle-fibers are composed of slender spindle-shaped cells containing elongated nuclei. These involuntary non-striated muscular fibers are woven in a continuous layer like a sheet muscle.

Contraction and dilation. Normal contraction of the pupil is brought about by stimulation of the so-called "pupillary light reflex arc" acting on the sphincter muscle, or by downward impulses along the efferent arm of this arc from cerebral stimuli, and dilation of the pupil is brought about by stimulation of the so-called "sympathetic nerve" acting on the dilator muscle, or by suspension of action of the pupil contracting mechanism in the brain.

The pupillary light reflex arc consists of a system of nerve fibers which have their origin in the retina and traverse the optic nerve along with the visual fibers, semi-decussating in the chiasm and reaching certain parts of the brain to end in small aggregations of cells, the "pupil centers." From there connecting neurons run to other centers in the brain, which in turn give off other neurons which enter the trunk of the 3rd nerve to pass on down into the ciliary ganglion in the orbit and entering the eyeball through the ciliary nerves finally reach the sphincter pupillæ.

A microscopic examination of a section of the optic nerve will reveal fibers of different sizes running in bundles. Some of these fibers are course and others are fine. The coarser fibers have nothing to do with the function of sight. They are the pupillo-motor fibers of the centripetal arm of the pupillary light reflex arc above referred to and are the nerve strands which are concerned solely in pupil contraction. They have been traced by von Monakow to the anterior colliculus of the corpus quadrigeminum. These fibers were first recognized by von Gudden and von Becterew. They have been studied and elaborated by Westphal, Reichardt, Piltz, Bach, Meyer, Bernheimer and many others, so that we may accept it as an established fact that these distinct and special coarse fibers of the optic nerve

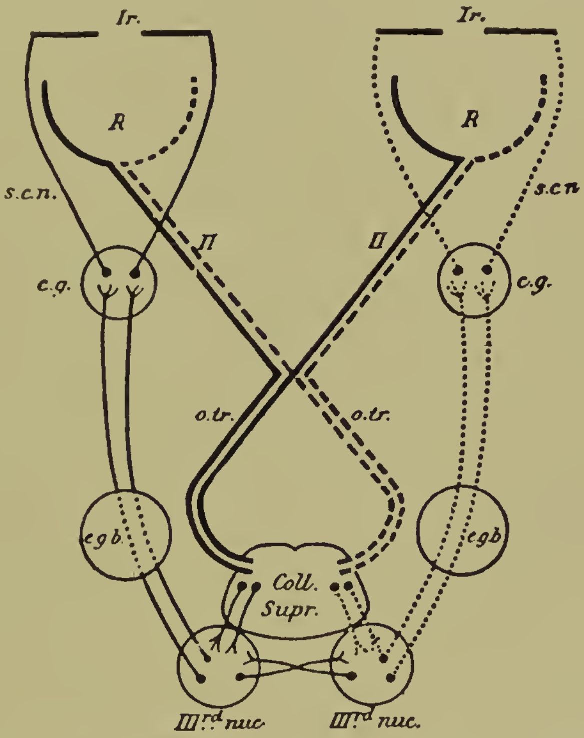


Diagram of the afferent and efferent pupillary paths for light stimuli. Afferent paths from left sides of retinæ, thick solid lines; afferent paths from right sides of retinæ, thick dotted lines; efferent paths of left eye, thin solid lines; efferent paths of right eye, thin dotted lines: Ir., iris; R, retina; II, optic nerve; o. tr., optic tract; Coll. Supr., colliculus superior or anterior corpus quadrigeminum; IIIrd. nuc., nucleus of third nerve; e. g. b., external geniculate body; c. g., ciliary ganglion; s. c. n., short ciliary nerves. (Description and diagram from J. Herbert Parsons.)

convey the stimulus from the retina along the optic nerve and optic tracts into their receiving nuclei in the brain to be translated into a motor impulse down from the brain to the sphincter pupillæ. (See figure.)

By testing the reaction of a person's pupil to light it is astonishing to note how quickly the pupil-contracting impulse travels to the brain centers and back to the iris. Exposing the eye to light produces a contraction of the pupil so quickly that sometimes it is difficult to catch it in the act. The up-going fibers are called the afferent, or centripetal, and the down-coming fibers are called the efferent, or centrifugal. Impulses travel along this arc in one direction only, viz., from the retina to the pupil center thence to the nuclei of the third nerve and from the nuclei of the third nerve to the sphincters.

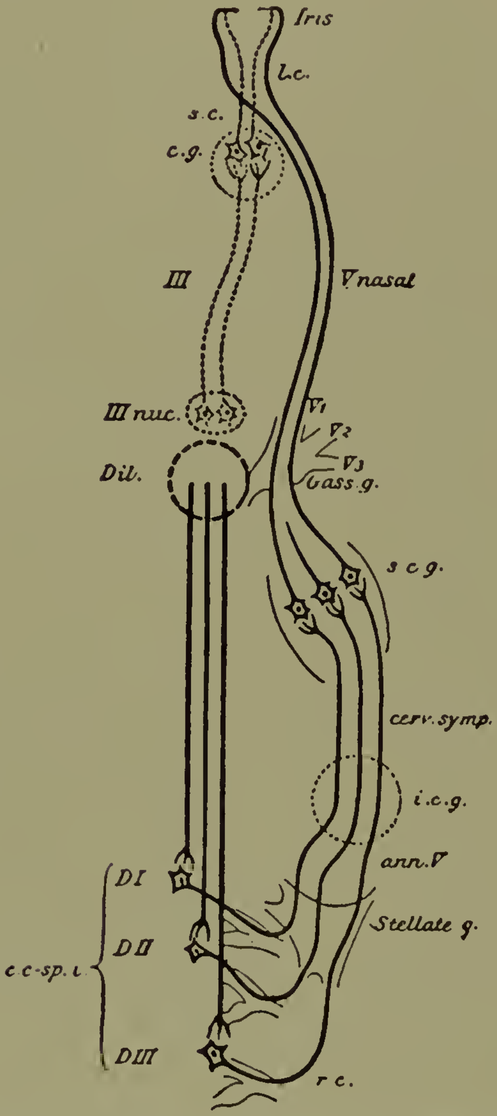


Diagram of the efferent pupillary paths. Dotted lines, pupilloconstrictor: III nuc., nucleus of third nerve; c. g., ciliary ganglion; s. c., short ciliary nerves. Solid lines, pupillodilatator: Dil., hypothetical dilatator center in the medulla; c.c-sp. i., Budge's centrum ciliospinale inferius; DI, DII, DIII, first, second, and third dorsal nerves; r. c., ramus communicans; Stellate g., stellate ganglion; ann. V, annulus of Vieussens; i. c. g. inferior cervical ganglion; cerv. symp., cervical sympathetic; s. c. g., superior cervical ganglion; Gass. g., Gasserian ganglion; V1, V2, V3, first, second, and third divisions of the fifth nerve; V nasal, nasal branch of the ophthalmic (first) division of the fifth nerve; l. c., long ciliary nerves. (Description and diagram from J. Herbert Parsons.)

It is possible for a person to be entirely blind from atrophy of the visual fibers in the retina and optic nerve and still retain normal pupillary reaction from the influence of light on the pupillomotor fibers. It is also possible for a person to be blind from a lesion affecting the visual areas of the brain cortex and still retain normal pupil-reaction.

The dilatation of the pupil is not brought about by any effect of light on the retina. On the contrary it may be brought about by the effect of *darkness* on the retina as well as from other causes through an active impulse conveyed to the dilator muscle of the iris along the cervical sympathetic nerve tract and at the same time a passive impulse conveyed to the sphincter. The nuclear origin of the cervical sympathetic is probably located in the medulla oblongata. The axis cylinders concerned in this pathway pass down the lateral column of the spinal cord sometimes as far as the 3rd dorsal vertebra to a certain spot in the cord known as the ''cilio-spinal center,'' or Budge's center. It is certain that this tract has connection with the cortex of the brain. Axis cylinders or neurons beginning at the cilio-spinal center emerge in the roots of the spinal nerves and reach the inferior cervical ganglion, passing en route through the stellate ganglion and the annulus of Vieussens; from the inferior cervical ganglion they pass on to reach the superior cervical ganglion near the angle of the lower jaw. This ganglion is a ''relay station'' where other neurons arise which in turn pass forward to where branching neurons from the Gasserian ganglion are received, and also neurons from the plexus around the internal carotid, and thus reinforced, as it were, they travel on to join the nasal branch of the first division of the 5th nerve (ophthalmic branch) to form the two long ciliary nerves which reach the ciliary muscle and iris. Paralysis of this nerve pathway causes contraction of the pupil through withdrawal of function: (See fig.)

The influence of the brain cortex on the pupil. It will be found that the claim has been set up, and probably proven, that there is a connection between the cerebral cortex and the centers for pupillary contraction and dilation. It seems difficult to prove a theory without definite laboratory findings. These fibers connecting the cortex with the sphincter and dilator nuclei have never been traced, but they most likely exist. *Haab's cortical reaction* is a stimulation of the centrifugal pupillary fibers from cortical impulse. Haab places the patient in the dark gazing straight ahead. A candle flame is placed at an angle of 45° from his axis of vision. If the patient directs his attention to the darkness ahead his pupils dilate, but if he directs his attention to the candle light at one side *without shifting his eyes in that direction,* the pupils will contract. This test seems to prove the claim that there must be in the brain a connection between the cortex and the centers for pupillary contraction and dilatation.

There are three kinds of nerves supplying the iris, all of which are concerned in controlling the pupil. They are (1) sensory, (2) motor, (3) sympathetic.

Sensory. In inflammatory states of the cornea and iris the sensory fibers cause local pain and produce a reflex contraction of the pupil. This contraction is brought about by the stimulus reaching the ciliary ganglion via sensory nerve strands and a return motor impulse along the strands of the 3rd nerve from this ganglion to the sphincter. There is also produced a certain amount of congestion of the blood vessels of the iris which in itself causes a narrowing of the pupil. The parent of the sensory nerves of the iris is the 5th cranial nerve.

Motor. Stimulation of the pupillomotor fibers in the retina and optic nerve as above described causes contraction of the sphincter pupillæ and consequent narrowing of the pupil space. The parent of the motor nerves of the iris is the 3rd cranial nerve. The nerve filaments which supply the sphincter pupillæ are in no direct way connected with the nerve filaments which supply the dilator pupillæ and yet there is a harmonious action between contraction and relaxation of the sphincter pupillæ and relaxation and contraction, respectively, of the dilator pupillæ. In no physiological state is there contraction of both the sphincter and dilator fibers at the same time. The impulse for contraction of the sphincter pupillæ may come from without through the influence of the light on the retina, or it may come from within, as when we bid the eyes to focus on an object near at hand.

Sympathetic. Stimulation of the sympathetic nerve fibers causes contraction of the dilator muscle in the posterior structure of the iris. This results in dilatation of the pupil. The parent of the dilating nerve fibers of the iris is the cervical sympathetic nerve as above described.

The practical application of our knowledge on the subject of the pupil is embraced in what is known as "pupillary reactions."

Normal pupillary reactions. There are two light-reflex pupillary tests in common use. The first is to determine the *direct* reaction which is produced when light and shadow are alternately made to enter the eye under observation. The second is the *indirect,* or *consensual,* reaction as when light and shadow are alternately made to enter the *fellow* eye. Both of these reactions when normal, are due to the integrity of the light reflex arc which we have just described.

The mechanics of the subject are embraced in the conversion of one kind of energy (light), to another kind of energy (motion).

The *associated* reaction is a contraction of the pupil which takes place in the act of convergence and also of accommodation.

The direct reaction of the pupil to light is a test which is applied to determine the state of the retina, brain or spinal cord, e. g., dilated fixed pupil may indicate paralysis of the brain or of the pupil center in the brain, or it may indicate irritation of the spinal cord from any cause, and contracted fixed pupil may indicate irritation of the brain (meningitis) or paralysis of the spinal cord or certain tracts in the cord. The indirect or consensual reaction is a test to determine the status of the pupillary light reflex arc. The associated reaction test is employed to determine the condition of the nuclear centers for convergence, accommodation and pupil contraction. The convergence reaction of the pupil is the most powerful pupillary reaction we have and the accommodation reaction is the weakest. If a person possesses only one eye the inference would naturally be that the convergent impulse would be lost and that if the pupil contracts it would be due to the effort of accommodation, but we must remember that even if one eyeball is removed the effort of convergence can be expressed in the remaining muscles of the orbit just as if the eye were present. The association between convergence and pupil contraction has been tested by forcibly converging the eyes by means of forceps and it is alleged that in this test the pupils will contract.

There are several other pupillary-reaction tests which are interesting.

I. So-called "Argyll-Robertson reaction:" In the Argyll-Robertson phenomenon, which is so commonly found in tabes dorsalis, we have contracted pupils at all times whether in light or darkness. The pupils do not contract to the light nor do they react when making the consensual test, but on employing the effort of convergence and accommodation they contract still further; so that we have a negative direct and consensual reaction, and a positive associate reaction. In this condition there is no interference with the fibers which run from the convergence center to the iris. It was formerly thought that the sympathetic nerve fibers running to the iris were paralyzed from degeneration of nerve elements in the spinal cord and the cilio-spinal center. This is now denied. The Argyll-Robertson phenomenon is present in about 75 per cent. of the cases of tabes. It is also frequently elicited in paresis, but here the pupils are not so contracted and they are apt to be unequal in size; moreover the phenomenon is apt to be of short duration in paresis, while in tabes when present it remains very constant. This pupil test is therefore very valuable in diagnosing tabes and paresis. The Argyll-Robertson pupil or spinal miosis may occur in other nervous diseases such as paralytic dementia, multiple sclerosis, injuries to the spine, etc. It never occurs in healthy individuals.

II. Psychical reflex or cortical reflex is a dilatation of the pupil through various mental stimuli. If a person makes a profound effort of the mind, as in deep thinking or concentration the pupils in health will dilate, or in terrified, angered or hypnotic states of the mind they will dilate. Cases have been reported where persons have caused the pupils to dilate while thinking of the dark or contract while thinking of the light. (Budge's reaction.) This test is allied to Haab's reflex which has been explained and proves there are fibers connecting the brain cortex with the nuclei of pupil-contraction and expansion.

III. Pain or sensory reflex has been referred to. When painful pressure is made on a sore spot any where in the body the pupils are seen to dilate. This is no doubt brought about through stimulation of the sympathetic nerve which supplies the dilator pupillæ.

IV. Hippus is a bounding of the pupil noticed while the light is unaltered. It is present to a certain degree in health when it is called "oscillations of the pupil." There is an arhythmical contraction and expansion noted while watching the pupil. It is, no doubt, incited from psychic influence, the patient is alarmed or apprehensive while undergoing the test. In certain cases of hysteria where there is a subnormal stability of the nervous system, and in some cases of meningitis, mania or partial blindness from optic papillitis, the pupil excursions in uniform illumination may be astonishing, actually bounding open and shut. This is "*hippus.*"

V. Wernicke's reaction test. In cases of hemianopsia when the light is focused on the blind half of the retina it is by some claimed that the pupil will not contract if the lesion involves the pupillary light reflex arc, but that if the lesion is in the brain cortex or any where above the pupil centers the pupil will contract if the blind half of the retina is illuminated. The test is not easy to elicit because, as Hess explains, it is difficult to illuminate one side of the interior of the eyeball and not have stimulation of the retina on the other side of the same eyeball from light reflected from the walls within the vitreous chamber; moreover, the light will stimulate the seeing half of the retina by passing through the sclerotic on that side, for the sclera will transmit light. That this test will differentiate a lesion at the base which affects one optic tract from a lesion involving the visual area is now disputed by many authorities.

VI. The Gallassi-Gifford reaction (also wrongly called Westphal-Piltz) is a contraction of the pupil noticed when the patient attempts to force his eyelids shut when they are held open, e. g., with a speculum. Von Graefe first noticed contraction of the pupil with strong effort at closing the eyelids. It is thought to be an "overflow stimulus from the nucleus of the facial nerve to the nucleus of the third nerve." (Gifford.) It has been elicited in mydriasis due to cerebral syphilis where the pupil was dilated and fixed. When the patient's eyelids were forcibly held open and he was told to shut them tightly, the pupils were seen to contract markedly. It may be used to differentiate a drug dilatation. In tabes when the pupils are small and fixed, they are seen to contract still more by this test. It is sometimes elicited in cases of blindness from increased brain pressure. It only shows that the sphincter nucleus and centrifugal fibers of the pupil reflex arc are not paralyzed.

VII. Paradoxical pupillary reactions are those which act just the opposite to the normal, e. g., on making the direct light test the pupils are seen to dilate or they may dilate when making the convergent effort; again they may be contracted in the dark and dilated in the light. Paradoxical pupil behavior is an occasional symptom of disease of the cerebro-spinal axis, e. g., tabes, paresis, dementia præcox, etc., or of a functional neurosis, as hysteria.

Etiology of abnormal pupils. Abnormal dilatation of the pupil is called mydriasis and abnormal contraction, miosis.

Mydriasis occurs in glaucoma, double optic nerve atrophy or total blindness from any cause which does not destroy the eyeballs. Mydriasis may also occur from the following causes:

(1) Anything which interferes with the function of the pupillary light reflex arc at any point from the retina up to the brain centers and down again to the iris, e. g., increased cerebral pressure will cause mydriasis through paralysis of the nuclear centers. The commonest causes are paralysis of the 3rd nerve from syphilis and ophthalmoplegia interna from degeneration of the cells in the pupillary center.

(2) Mydriasis may occur through psychic or cortical influence, as in maniacal or frenzied states of the mind.

(3) Temporary anemia of the brain, as in fainting when the reflexes are abolished temporarily through heart failure, etc.

(4) Paralysis of the brain, as in fatal syncope, over-dosing with general anesthetics, oncoming death, etc.

(5) Locally from certain mydriatic drugs such as cocain, atropin, daturin, duboisin, hyoscyamin, homatropin, gelsemin, euphthalmin, etc. Constitutionally from poisonous doses of certain other drugs as aconite, cannabis indica, chloral, chloroform, cocain, conium, digitalis, ergot, gelseminum, nitrite of amyl, nitro-glycerine, sanguinaria, stramonium, turpentine, scopolamin, wood-alcohol, quinin, etc., some of these in physiological doses produce contracted pupils but all in lethal doses produce dilatation.

(6) Dilatation of the pupil also results from stimulation of the sympathetic nerve supplying the dilator pupillæ, such as noted in sensory skin and painful pressure reaction, pinching the superior cervical sympathetic ganglion or sticking pins in it, as in a case of hysteria in a nurse who wanted to be operated on for imaginary brain abscess; spinal irritation from any cause such as traumatism, myelitis, spinal meningitis in early stages, gastric and intestinal disturbances which incite unconscious states, as convulsions in children, as well as teething, shock, real and psychic, a good spanking, a ghost story, night terrors, anything which makes "the skin creep and the hair to stand on end" will stimulate the sympathetic nerves to the iris and cause pupil dilatation.

We must be able to diagnose in a given case whether the dilatation is paralytic, as from paralysis of the brain or its nuclei, or spastic, as from excitation of the spinal cord causing stimulation of the cervical sympathetic nerve. In many of these cases, if not the majority, there is a simultaneous withdrawal of contracting impulse through the 3rd nerve filaments going to the sphincter and stimulation of the dilating impulse along the sympathetic to the dilator muscle.

Miosis. (1) Iritis, ulcers and abrasions of the cornea from congestion of the iris blood-vessels and reflex sensory irritation.

(2) Plethoric states of the brain, as in acute high fevers, acute meningitis from any cause, uremia, alcoholism, etc.

(3) Paralysis of the sympathetic from any cause be it central, intermediate or peripheral.

(4) From certain drug influence as when escrin, physostigmin, pilocarpin, or arecain in solution is dropped in the eye.

(5) Poisons inwardly, as opium and its salts, carbolic acid, creosote, alcohol in lethal doses, chloral at first, jaborandi, pilocarpin, muscarin, etc.

We should keep clearly in mind that paralysis of the sympathetic nerve from any cause contracts the pupil to a pin point (spinal miosis) and that paralysis of the brain causes widely dilated and fixed pupils; while stimulation of the spinal cord causes dilatation and stimulation of the brain causes contraction of the pupil. In giving general anesthetics we must decide whether the sudden dilatation of the pupil sometimes present is due to spinal irritation from gastric disturbance or whether there is oncoming paralysis of the brain. In suspected poison-cases we must decide whether the contracted pupil is from opium or from uremia. In suspected "drunks," whether the contracted pupil is from alcohol or meningeal irritation due to apoplexy, uremia or sunstroke. We must look at the pupils in suspected acute tuberculosis or pneumonia of one lung for that slight dilatation that is a sign. We must note and understand the hippus in hysteria, chorea or mania, the widely dilated pupils due to increased brain pressure in brain tumors or brain abscess, the dilated pupil on one side in hemorrhage in one hemisphere of the brain, the Argyll-Robertson pupil in spinal syphilis, the unequal, deformed, and more or less fixed pupils in general paresis or cerebral syphilis, the normal pupils in sham fits.

The behavior of the pupils in health and disease affords a valuable and interesting study to any one who understands the impulses controlling the phenomena of pupil contraction, expansion and rigidity.

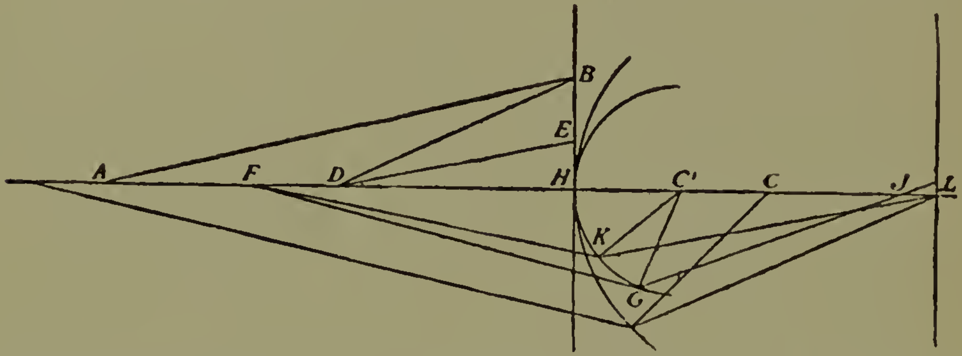
PUPILLARY CONDITIONS AND ANOMALIES NOTED IN ALPHABETICAL ORDER.

Accommodation, Pupil contraction depending on. Hess (*Klin. f. Augen.*, June, 1912, p. 740), is satisfied from observation on patients and from tests with his own eyes that the contraction of the pupil in near vision is dependent on accommodation effort and not on convergence. He had three cases of right third nerve palsy in each of which there was contraction of the pupil and marked increase of accommodation noted (7 D. in one case) when the patient fixed at the reading distance with his left eye, the right being observed behind a shutter. There was no convergence whatever but the pupil contracted during the test.

He tested his own eyes by means of a stereoscope with transparent pictures. While disassociating his convergence and accommodation he would see a distant object clearly and the two transparent stereoscopic pictures in a blurr in spite of their being combined. He would then accommodate, not changing the position of his visual axes and he saw the stereoscopic picture clearly while the distant object was in a blur. Two observers noted his pupils contract when using his accommodation and dilate when fixing the distant object in spite of the fact that his visual axes were unchanged in both acts.

On the other hand Wlotzka (Pflueger's *Arch.*, 107. 3 and 4, p. 175) investigated to determine whether contraction of the pupil is brought about by the effort of accommodation and found quite the opposite phenomenon. He had the subject focus his eyes on a disk several meters distant. He then placed a half-disk to intercept each visual axis midway between the eyes and the distant image so that the patient could fuse these half-disks binocularly. By looking at the distant disk and the half-disks the convergence remained the same but the accommodation on fixing and fusing the half-disks was compelled to act. Observation of the pupils in this act revealed them unaltered, therefore he maintains that the accommodation is independent of pupil contraction.

Accommodative pupillary movements. Weidlich (Knapp's *Archiv. Ophth.,* November, 1907, Vol. XXXVI, No. 6, p. 819) reviews that part of physiologic optics which deals with the passage of rays of light from different distances through the pupil that is dilated and also contracted, proving that the pupil in health accommodates the eye to different distances in dispelling spherical aberration and diffusion circles. He uses the following diagram and the legend (see fig.) to illustrate the well known fact that when the eye is focused on the near point the anterior surface of the lens represents a sharper curve (changing from a 10 mm. to a 6 mm. radius curve) and that therefore the pupil must accommodate the eye by contracting and cutting off the spherical aberration to permit the needed increased acuity of vision. Nature has so arranged this mechanism that in



The upper half of the drawing represents the pupillary plane placed in the principal plane of the reduced eye. The bundle of light from A, enclosed by the angle B A H, passes through the upper half of the pupil H B. If the pupil remained the same size for the bundle of light coming from D, the angle B D H > B A H. If D E is made parallel to A B, however, the angle E D H = B A H.

The lower half of the drawing shows that with a more marked curvature about C′ as a centre, a shorter arc corresponds to the same angle in the case of the less marked curvature about C as a centre; consequently the peripheral ray F G is refracted more strongly to J, whereas the more central ray F K is not refracted so strongly to L.

each condition of the dioptric system there is the greatest acuteness of vision elicited with sufficient illumination.

Acoria or congenital absence of the pupil, is due to some fault in the usual program followed by nature in the formation of the iris.

The vascular sheath of the lens develops in the early weeks of pregnancy and is concerned in the growth of the lens. The iris "grows in" from the edge of the optic cup at the sclero-corneal angle. When the anterior chamber forms, which is by the 7th or 8th month of pregnancy, the iris is completely formed and the pupillary membrane has completely resorbed. In the production of this rare anomaly, either the iris continues to grow till it meets at the center leaving no pupil, or the pupillary membrane from the persistent hyaloid sheath of the lens completely fills the gap designed for the pupil. In the former case there is true acoria; in the latter pseudo-acoria, which more properly belongs to the discussion of forms of congenital cataract. In either event the condition is exceedingly rare. Associated with it is invariably the condition known as microphthalmia.

Adaptation of pupillary reflex to darkness. Hess (*Arch. of Ophth.*, March, 1909, Vol. XXXVIII, No. 2, p. 140), investigating with his pupilloscope found that there is in the human eye an adaptation in the dark not only for light perception, but also for the pupillary reflex. He noticed that a smaller quantity of light suffices to excite pupillary contraction in an eye adapted to the dark than in one adapted to the light. He took advantage of this fact in proving his theory that only the central part of the retina embraced in the macula and adjacent area, and possessing a radius of not more than 3 mm., is the only place where the pupillomotor fibers exist. His tests demonstrated that when the same volume of light was shifted from one portion of the retina to another away from this area there was in an eye adapted to the dark no change in the diameter of the pupil. Moreover, that when the smallest degree of light strength which would excite a pupillary contraction in the eye adapted to dark was cast upon the parts of the retina not possessing pupillomotor fibers, there was no contraction of the pupil.

Hess states that the result of his experiments was a surprise to him, for he had undertaken the observations with the idea that the peripheral retina partook in the production of the pupillary reaction and he had perfected the apparatus based on this theory. He answers the argument of the advocates of the theory that the entire retina possesses pupillomotor fibers which decrease towards the periphery and therefore that a point of strong light thrown on the retina will show the same amount of contraction of the pupil as a weak light on the macula, by stating that the same result will be produced even if the center alone is pupillomotoric because of the diffused light which will stimulate the motor area when thrown on the periphery of the retina.

Hess' discovery that the pupillomotor fibers only exist in a small area of the center of vision affords new view-points regarding the behavior of the pupil in certain diseases. (See *Pupillomotor fibres*, also *Threshold value* and *Light coefficient*, in this section.)

Adrenilin, The action of. Weekers (*Arch. d'ophtalm.*, XXXII, p. 610), reports three observations of a characteristic reaction of the pupil to adrenalin in cases where the sympathetic nerve was paralyzed causing miosis. In these cases cocain drops caused little or no dilatation of the pupil but adrenalin solution dropped in the eye caused prompt dilatation. (See *Glycosuria* in this section.) He maintains that with this test in miosis we can produce a specific reaction pathognomonic of a paralytic lesion of the cervical sympathetic nerve for it produces a dilatation of the pupil *only* in cases where this nerve is affected. He found the degree of dilatation was proportionate with the amount of paralysis present.

Lewandowsky (*Arch. f. Anat. u. Physiol.*, 1899, p. 360), reports that intravenous injection of adrenal extract caused dilatation of the pupil in animals.

Van der Scheer (*Neurolog. Zentralb.*, 1915, 17), conducted over five hundred observations to note the effect on the pupil of adrenalin drops in the eye. It has been claimed that adrenalin produces a change in the size of the pupil, either causing contraction or dilatation, in patients presenting mental disorders, while in normal persons it produces no such change. He finally concluded that the test is of no diagnostic value.

Adrenilin, The synergetic action of, in combination with atropin. Erdmann (*Zeit. f. Aug.*, 32, 1914, p. 216), experimented on rabbits using adrenalin solutions subconjunctivally. He decided adrenalin was synergetic to atropin and was able to break up firm adhesions at the pupil margin in human eyes by the subconjunctival injection of adrenalin with atropin. The danger of causing hemorrhages in the anterior chamber is mentioned.

Agitans paralysis. The pupils are unaffected in size or reaction in paralysis agitans.

Albinism. Fuchs (Text Book, 4th Am. Ed., p. 82), explains the luminous shine seen in albinos' pupils. "In such eyes the light passes not only through the pupil, but also through the unpigmented iris and even through the sclerotic, thus the whole interior of the eye is flooded with light and there being no pigment to absorb this light it is reflected from all parts of the fundus of the eye and therefore, the rays from different portions of the fundus pass out of the pupil in every direction and can very readily be caught by the observer's eye.'' Fuchs proves this to be the correct theory by holding an opaque screen with a perforation the size of the pupil in front of the albino's eye. By this test it is observed that the pupil is no longer luminous but black in appearance.

Lagleyze (*Arch. d'Ophtalmologie,* June, 1907), made a critical study of the eyes of albinos and deducted valuable and interesting data. He found the pupils presented the following conditions: ''The pupils are usually small, dilate but little in feeble light and react regularly. They are usually displaced inward and upward, the shadow of the brow and bridge of the nose causing an unequal contraction of the sphincters.

Libbey (*Ann. Ophthal.,* April, 1910), used eserin and atropin in cases of complete albinism and found that the former caused contraction of the pupil to 1.5 mm. and the latter caused dilatation to 6 mm. Most interesting was the observation of the diameter of the lens as seen through the transparent iris in a dark room. In eserin the diameter measured 8 mm. and in atropin it measured 10 mm.

Albuminuric retinitis of pregnancy. While in this disease there is a condition similar to that found in uremia the pupils are usually seen to be somewhat dilated, which is just the opposite to what we find in uremia. The explanation of this must be that the vision in albuminuric retinitis of pregnancy is so impaired that the stimulus of the light is lost on a sodden retina.

Alcoholism. Nonne (*Neurolog. Zentralbl.,* 1912, No. 1) saw clearly defined reflex immobility of the pupil with slight mydriasis in an alcoholic fifty-one years old. The man had neither syphilis nor tabes, and Nonne holds that the pupillary phenomenon observed in this case, which was undoubtedly due to toxic influence, was extremely rare.

Minck found miosis in delirium tremens during the maniacal, and mydriasis during the terminal phase. Others have noticed pupil irregularities mostly anisocoria.

Brunton (*Brit. Med. Jour.,* December 1st, 1900) stated that in a case of alcoholic neuritis involving the trigeminus the pupil reflex to light was just the reverse of that noted in the Argyll-Robertson phenomenon. When testing with the light the pupil responded rapidly and fully, but contraction to accommodation was sluggish or entirely wanting. In one of the two cases, he observed dilatation instead of contraction during the effort of accommodation.

Scherwinzky (*Arch. f. Ophth.*, 87, p. 135) reports the case of a heavy drinker who imbibed methyl alcohol, producing blindness. In this case the pupils were extremely narrow and did not react to light. This is contrary to the usual observation in cases of this kind. We usually find the pupils dilated widely and associated with acute atrophy of the optic nerve, but Scherwinzky's case presented symptoms of uremic poisoning as well, and here we have the overwhelming effect of the latter producing the contracted pupils. One must always be watchful for causes producing atypical pupils.

Mees (*Muench. med. Wochensch.*, 1913, No. 14, p. 721) saw a patient with multiple neuritis from alcohol in whom both pupils were immobile and much contracted. After he recovered from the alcoholism the pupils became normal.

Amaurotic family idiocy. In this disease, which occurs among infants appearing normal at birth, but which in the early months of life begin to show signs of blindness and on-coming idiocy, it is a remarkable fact that the pupils appear normal in size and reaction in nearly all of the cases. The optic nerves may be quite atrophied, the fundus presenting the unmistakable signs of the disease, blindness may be nearly, if not entirely complete, but the pupils usually are small (which is the case in normal infants) and respond when light is flashed in the eyes. This was true in cases reported by Magnus, H. Knapp, Sachs, Hirschberg, Kingdon and others (see *Arch. of Ophth.*, November 1900, Vol. XXIX, No. 6, pp. 602-617). However, in a case reported by Verhoeff (*Arch. of Ophth.,* March 1909) the pupils were large and reacted to the light.

Amplitude in convergence. Bach (*Zeit. f. Augenh.*, XII 6, p. 725), observed that the amplitude of the convergence reaction of the pupil ranges from 1/4 mm. to 3/4 mm. It is well-marked in the Argyll-Robertson pupil and may persist in cases with almost complete accommodative paralysis.

Amyotrophic lateral sclerosis. This progressive disease involves the anterior horns of the spinal cord and finally reaches the different nuclei in the medulla and pons, giving rise to bulbar symptoms. If the dilator pupillæ center is involved we have miosis with retained associate reaction. The pupils are often unequal in size. The phenomena are explained by involvement of the cervical sympathetic nerves.

Anesthesia, General. E. R. Northrop (*North-west Medicine*, April, 1906), states the pupillary reaction is the best guide as to the patient's condition while under the effect of an anesthetic. A rapidly dilating pupil is a signal of danger and a fixed, dilated pupil extreme danger. A contracted immobile pupil usually means safe surgical anesthesia. Oscillation of the pupil means diminished narcosis. Sometimes the pupil dilates when painful parts are manipulated while the patient is fully under the anesthesia. (See *Sensory reflex* in this section.) In the beginning stages of anesthesia the pupils are usually somewhat dilated but they respond well to the light, as the anesthetic is pushed the pupils contract more and more and react less and less until they finally become well contracted and fixed—as the anesthetic wears off the pupils gradually return through the same series of changes reversed, or they dilate suddenly when the patient struggles or begins to retch.

The contracted pupil is the safe pupil in anesthesia, and if the pupil still responds when the other reflexes are absent we may know that the patient is not profoundly anesthetized.

When chloroform is being used I have seen the pupil dilate in primary anesthesia, either from the overwhelming effect of the drug on the vital centers of the brain, or a syncope from sheer fright on the part of the patient.

Parsons, of Denver (*N. W. Medicine,* March, 1911), remarks that the pupil should be contracted during the third stage of surgical anesthesia. There is, however, a stage of false anesthesia in which the pupils are minutely contracted (1.0 mm.) and yet the patient is not unconscious. This finding is particularly frequent among infants and children. I have noticed it also in the primary stage of anesthesia where chloroform is used. There is a short stage of complete anesthesia similar to that produced by nitrous oxide soon after the chloroform mask is applied; during this stage the pupils are quite contracted.

Parsons wisely states that the anesthetist should know whether the dilated pupil during anesthesia is of reflex or paralytic origin. If reflex dilation is present, we are to understand that there is irritation of the cervical sympathetic nerve from gastric influence for it is noticed just before an attack of vomiting. If there is paralytic dilatation the narcosis is too profound and death is dangerously near. Parsons offered the following differential table:

Reflex dilatation: Pupil is bright, mobile, liquid, likelife. Paralytic dilatation: Pupil is dull, sluggish, immobile, death-like. Reflex dilatation: The pupil reacts to light. Paralytic dilatation: There is no reaction to light.

The anesthetist must judge the patient's condition from other symptoms as well. The pallor of the patient's face and lips, together with a death-like stare in paralysis of the brain declares a patient to be dead from the anesthetic.

Anesthetics, Local, that have no effect on the pupil. It is well known holocain in one per cent. solution is a powerful anesthetic of speedy action since it causes more or less anesthesia of the cornea in from one to three minutes and does not affect the size or behavior of the pupil.

Alypin in 4 per cent. solution has been used as a local anesthetic in ophthalmic practice and it does not cause dilatation of the pupil.

Anatomy of the atropinized and eserinized human eye. Lange (*Ophth. Soc. Trans.*, Lower Saxony, Hanover, May 16, 1909), placed the eyes of a newly-born infant quickly enucleated after death, one in warm 5 per cent. solution of atropin, the other in a similar solution of eserin. Marked mydriasis soon after took place in the one and marked miosis in the other. These eyes were hardened and sectioned. In the atropinized eye the pupil measured 6 mm. the iris root was thickened, the angle of the anterior chamber was narrowed and the lamellæ of the ligamentum pectinatum were closely crowded, the spaces between them being scarcely visible.

The same section of the eserinized eye showed the pupil to be 3 mm. in diameter, the root of the iris thinned, the angle of the anterior chamber wide and the lamellæ of the ligamentum pectinatum separated, the spaces between them being very wide. These observations prove beyond doubt the baleful effect of mydriatics in eyes that are disposed to glaucoma and at the same time prove the beneficent effect of myotics in cases of glaucoma-storms, threatening and established. (See *Death-experiments with atropin and eserin,* also *Tension influence in this section.*)

Anatomy of the filtration angle of the eyes. Thomson (*Ophthalmoscope*, September, 1910), demonstrated that there is a well-marked recess, like a groove, on the corneal side of the filtration angle in the normal functionating human eye. When the pupil dilates this groove receives the thickened iris and when the pupil contracts it is obliterated by traction exerted by the iris. This anatomical and physiological arrangement assists the circulation of the aqueous at the angle of the anterior chamber. (See *Musculature* in this section.)

Anemia, pernicious. In pernicious anemia there is degeneration of the posterior and lateral columns in the spinal cord, which may also extend to the anterior part of the cord. The pupils are usually unequal in the terminal phase of the disease. When the cervical sympathetic is affected we find bilateral ptosis and marked miosis. In a few cases dilated and fixed pupils have been reported (de Schweinitz). In these cases optic neuritis and blindness had set in, hence the dilated pupils.

Angiosclerosis and hypertension. In the aged possessing high systematic blood pressure the pupil is found to be somewhat contracted, certainly much smaller than in middle life and it responds somewhat feebly to the light. The patients may have normal vision, in fact increased acuity on account of the small pupil cutting off the circles of diffusion. I have seen instances of this kind where the patient past sixty years of age was able to see 20/20 and also read Ja. No. 1 at thirteen inches without the aid of lenses. The condition should be diagnosed an abnormal one and the suspicion of impending cerebral apoplexy, or apoplectiform retinitis, should arise. These eyes are not good to operate on for cataract on account of the danger of an expulsive hemorrhage from the friable choroidal vessels. (See *Wiener and Wolfner's reaction* in this section.)

Hirsch states that in arterio-sclerosis the shape of the pupil may become slightly changed. It may be oval instead of circular, or show some other irregularity of its circumference. (Posey and Spiller, *The Eye and Nervous System,* p. 466.)

Aneurism of the orbit, Aneurism of the cavernous sinus, Pulsating proptosis. In the cavernous sinus the third nerve anastomoses with the sympathetic and also with the supraorbital branch of the fifth nerve. Hence, aneurism of the cavernous sinus is usually associated with paralysis of the sphincter pupillæ, causing dilated pupil. There is an interesting ocular paralytic syndrome associated with this disease but our present theme is only concerned with the study of the pupil. In a case cured by ligation of the common carotid there still persists mydriasis which is the only ophthalmic symptom now present, the cure otherwise being complete. This would seem to argue the excessive vulnerability of this strand of nerve fibers as compared with other branches of the third, for the strabismus, ptosis, and ophthalmoplegia have all disappeared.

However, Belt (*Arch. of Ophth.,* July, 1901, Vol. XXX, No. 6, p. 391), reports a case of pulsating exophthalmos in which the pupil was contracted when examined some 24 hours after the onset. A physician who examined the patient only a few hours before the onset, reported that the pupil was contracted at that time. Two days later the pupil was still contracted in spite of the fact that the eye was blind.

Aniridia implies congenital absence of the iris in contradistinction to irideremia, which is acquired absence of the iris, a post-traumatic state which will be explained later on. Collins and Mayou, in their text book on *Pathology and Bacteriology of the Eye,* state "Apparent entire absence of the iris is always a bilateral affection."

There are two forms recognized, viz., (a) complete and (b) partial aniridia. The former is more often apparent than real for if section be made through an eye that appeared to possess complete aniridia, apron-like vestiges of iris, expressed in nodules or crescentic strips will usually be found projecting a short distance from the ciliary attachment of the iris root. They are often feebly expressed and so rudimentary that the most careful examination by the refined later-day methods *in vivo* will fail to reveal the presence of iris vestiges.

In complete congenital aniridia the pupil occupies the whole of the corneal area. Congenital absence of the iris presents an interesting study in embryology and physiology, for in the first place we usually find other signs of imperfect architecture of the eye, such as rudimentary lenses, congenital absence of the macula lutea (so-called "congenital amblyopia"), one or another of the various forms of congenital cataract, etc., and in the second place the pupillary light reflex arc which in normal states is constant and which has an interesting association with ciliary action, is non-functionating. It has not been proven that the centripetal and centrifugal pupillary fibers which run from the retina to the pupil center in the corpora quadrigemina, and thence back again to the iris, are absent, but if present they cannot functionate for there is no iris sphincter present to respond.

Collins and Mayou (1. c.) state that the predisposition to chronic glaucoma noticed in cases of congenital aniridia is explained by the fact that "the angle of the anterior chamber appears imperfectly opened up, adhesions stretching across it between the dwarfed iris and cornea."

When one considers how the pupil is formed embryologically, by an ingrowing of the edge of the optic cup at a certain stage of ocular development, he wonders that congenital pupillary anomalies are not more commonly met with. The iris does not begin to grow until after the lens is ensheathed with the hyaloid vascular membrane, at which time it is in contact with the forming cornea. The edge of the secondary optic vesicle must now force itself between the fibro-vascular sheath and the lens. The branches of the ciliary vessels which anastomose with the branches of the hyaloid to form the anterior vascular sheath of the lens afford certain resistance to the ingrowing of the edge of the optic cup to form the iris and it is curious that the atrophy and resorption of these blood vessels should be so well timed with the advance of the iris-forming cells. If there are adhesions, e. g., between cornea and lens or between the edge of the posterior vascular sheath and the periphery of the cornea, there would be offered a resistance to iris development at such places. This will account for the cases of *partial aniridia*, atypically placed colobomata of the iris with the resultant *corectopia, discoria,* or if reunion of the arms of the coloboma takes place beyond the adhesion above referred to, the *polycoria.* In all of these we note the pigment layer of the iris is corrugated and extends quite around the edge of the nodule representing the undeveloped part of the iris, thus producing the so-called ''ectropion of the uveal pigment.''

A case of aniridia was reported by Williams before the Chicago Ophth. Society, April 12, 1909. It was in a girl of nine who had microphthalmus and a high degree of amblyopia and congenital cataracts. Attempts were made to supply her with crossed stenopaic slits mounted in spectacle frames and combined with myopic lenses. This arrangement brought the vision up to marked improvement and entirely controlled the photophobia.

John Greene, Jr. (*Ophth. Record,* April, 1909, Vol. XVII, No. 4), reported a case of congenital aniridia. There was no ''pupil'' in either eye, or the eye showed ''all pupil.'' In the discussion Saxl stated he had seen two such cases. Cataract was present in all cases observed.

Holloway (*Ophth. Record,* September, 1913), reported a case of complete bilateral congenital absence of the iris associated with ectopia lentis.

Juler, of London, found after removing the eye for glaucoma, which had developed in a case of congenital aniridia, that there was a ring of iris at the extreme periphery which had caused blocking of the angle.

The literature is well supplied with reported cases of this affection, so that it is not uncommon.

Aniridia, Complete traumatic. Irideremia totalis. Complete traumatic aniridia has been observed many times but there is often a vestige of iris at the root which is hidden behind the margin of the cornea. The vision may remain permanently good, or glaucoma may supervene, which is the usual program.

It is a curious fact noted by Faith, of Chicago, that cases of complete traumatic aniridia in which glaucoma developed as a clinical symptom, the same was relieved by the application of eserin drops. Since the benefit following the myotic remedy in this disease is ascribed to the contraction of the iris sphincter it is inharmonious with that theory to have the tenson of the eye reduced by the use of eserin drops where no iris sphincter exists.

In an unreported case of traumatic aniridia (irideremia) which occurred in the practice of the writer, the young man (age 30) presented complete absence of the iris and there has been no glaucoma in evidence after six years' time. The patient has normal vision, normal fields and normal accommodation in this (his right) eye, and he has suffered no inconvenience from the accident whatever; there is no photophobia and no aberration present. The red reflex test is most striking as it occupies the entire cornea. The following notes were taken: "By using the red reflex test and having the patient direct his eyes at infinity, the dark line representing the periphery of the crystalline lens can be discerned and a bright zone beyond this which represents the circumlental space occupied by the transparent suspensory ligament. By having the patient accommodate on an object suddenly held at the reading distance, while the observer still maintains the red reflex with his attention centered on the lens periphery, he will *see* the contraction of the circumference of the lens and the shifting of the circumlental space, thus positively demonstrating the truth of the theory that the sphincter ciliary contracts in the effort of accommodation and that the horizontal diameter of the lens decreases and the sagittal diameter increases."

It would be presumed that patients having congenital aniridia would suffer from dazzling but such is the adaptability of the eye in states of health that these patients are not in ordinary light annoyed by photophobia. They usually have, however, a frowning expression, or what is miscalled in common parlance "squinty habit," which is not so much due to the irritation of the light (as would be conjectured) as a desire to clear the circles of diffusion on the retina thus increasing the visual acuity. If such patients be instructed to open their eyes widely while the strongest light is directed in the eye with the ophthalmoscopic mirror they can do so with impunity and with no apparent symptoms of photophobia. (See *Rupture of the iris* in this section.)

Anisocoria. Significance of pupillary inequality. Hansell (*Ophthalmology,* Jan., 1908), states that inequality in the size of the pupils may be normal or may exist from the following causes: (a) paralysis or paresis of one sphincter pupillæ supplied by the third nerve, causing monocular mydriasis, or (b) paralysis or paresis of one dilator pupillæ supplied by the sympathetic, causing monocular miosis. The anisocoria may be due directly to intra-ocular disease, e. g., glaucoma, iritis, atrophy of the retina, detachment of the retina, etc., and in this instance the finding does not enter into the study of the significance of the symptom as a diagnostic feature in constitutional disease.

Inequalities of the pupils are present in so many diseases of the cerebro-spinal and circulatory systems that, taken alone, they are of doubtful value. Moreover, many functional diseases (neurasthenia, hysteria) and many neuroses and psychoses, as well as some intoxication states, present the symptom in common so that the cause in each instance must be sought for by the presence of other symptoms, just as is true in the case of fever which is a symptom of so many varied and diverse diseases that taken alone it presents no localizing or diagnostic features.

Hansell states that pupillary inequalities have always been regarded with suspicion of some grave affection of the central nervous system presenting a serious prognosis, but that after investigation he has now come to the conclusion that no such sinister conclusion from the symptom should be drawn. In the first place the investigations of Schaumann (*Zeit. f. Augen. Klin. Med.*, 49, p. 61), show that among healthy children of the public schools, and also among medical students, anisocoria was found to be present in frequency varying from 4 to 10 per cent. Ivanow claims to have found it in 91 per cent. of 134 normal persons and Felton in 28 out of 61 individuals. The marked difference of opinion of observers on this point is to be explained by the different methods of examination and the equations of the examiners. Paralytic mydriasis of one pupil is not, however, to be classed as a normal state for it usually implies paralysis of the filament of the third nerve supplying the sphincter pupillæ. The lesion may be central, intermediate or peripheral. Each case must be studied and other symptoms carefully gone over in order to make a definite diagnosis. In some cases it is a symptom of irritation of the dilator pupillæ, as when the causative lesion exists in the neck contiguous to the strands of the sympathetic, e. g., enlarged glands, aneurism of the carotid whereby the carotid plexus or cervical ganglia or nerves are irritated. In many internal diseases monocular mydriasis may be noticed as a symptom. Schaumann (*Berl. Klin. Wochensch.*, 34, 1897), estimates 23 per cent. of all internal diseases at some time in their courses give rise to the symptom. He mentions lung affections, pleuritis, cardiac disease, chorosis, pernicious anemia, appendicitis, diabetes, neurasthenia and hysteria. There is one grave disease in which a partially dilated and slightly sluggish pupil is a rather constant symptom and that is *paresis.* (See elsewhere in this section.)

Anisocoria and anisometropia, The relation between. Some have maintained that in anisometropia the pupil is wider in the more defective eye, but Frenkel, as well as Bach, maintains that there is no definite relationship and that they have observed no difference in the size of the pupils in anisometropia, and moreover that when differences have been noticed, the wider pupil is just as frequently on the less defective side. (See *Inequality of the pupils* this section.)

Anisocoria. Schaumann examined 1,168 patients as regards inequality of the pupils and found 27.9 per cent., and in another series of 723 patients 37.8 per cent., presented anisocoria; males and females were about equally affected. The left pupil was more often the larger. Inequality of the pupils was noted more often among patients affected with some form of neurosis than among those presenting evidence of bodily disease apart from the nervous system. In some no evidence of disease of any kind could be traced and in these the anisocoriæ were regarded as being physiological anomalies. One must therefore distinguish between the symptomatic and the idiopathic forms of anisocoria. The "see-saw" pupils that Schaumann had observed were present in eleven of his cases and he regarded them all to be the subjects of hysteria.

Aortic aneurysm. Babinski (*Bull. de la soc. de Paris,* November 8, 1901), reports two cases of unequal pupils in cases of aortic aneurysm which he thought were not to be explained by the generally presumed compression of the sympathetic. Both patients had the Argyll-Robertson phenomenon and he therefore concluded that the pupils in these cases of aneurysm were due to syphilis rather than to any influence produced by the aneurism. (See *Pupil reflexes in mitral cardiopathies* in this section.)

Anthropometry. Pollak (*Wien. Med. Wochensch.,* Sept. 16, 1899), discussing the value of records of ocular peculiarities in the identification of criminals according to the Bertillon system, states the pupillary distance becomes a valuable means of identification. He recommends that measurements be made from the center of the nasal bridge to the center of each pupil. The pupillary distance bears a certain relation to the breadth of the skull.

Argyll-Robertson pupils in tabes. The so-called "Argyll-Robertson pupils" are very characteristic if not pathognomonic of tabes, and they make their appearance in advance of any and all other symptoms of this disease. Sometimes the pupil will show unmistakable signs of tabes several years in advance of the other symptoms. It is important therefore for the ophthalmologist to understand the pupil behavior in this disease for he is very often able to make a positive diagnosis far in advance of the actual development of the disease. It is unwise, however, to acquaint the patient of the fate which awaits him, for merciful reasons, if for no others. When a cure for the disease is discovered, the ophthalmologist will occupy a position of great value in relation to the welfare of the patient who exhibits the unmistakable pupil symptoms of tabes; as it is at the present time, however, much harm and unhappiness results from informing the patient that he is a marked tabetic. Argyll-Robertson first called attention to the peculiar behavior of the pupil in tabes dorsalis. He noted that in this disease the pupils were contracted and did not respond to light, but that no matter how great the miosis was that there was further contraction when the patient employed the effort of convergence and accommodation. It is by many believed that the miosis is caused by paralysis of the dilator pupillæ muscle through degeneration of the cervical sympathetic nerves at their origin in the spinal cord. Babinski mentions two patients who had Argyll-Robertson's pupils in whom it was demonstrated that while the phenomenon was positive to the ordinary tests, if the eyes were bandaged for half an hour and the test repeated the pupils responded nicely. Babinski explained this by assuming a retinal reaction.

While the majority of cases of tabes show contracted pupils with absent direct reaction and retained associated reaction throughout the course of the disease, cases have been noted in which the pupils were normal except during the gastric crisis, when the Argyll-Robertson phenomena were noted. Other cases have been reported in which the typical pupils were manifested intermittently. The symptom is more manifest in confirmed and well established cases than in incipient ones. In the former, studied by Dillman, Argyll-Robertson pupils were present in 76 per cent., while in the latter, 23.7 per cent. of cases. Other observers found over 80 per cent. of cases of tabes with Argyll-Robertson pupils, while Pearce in a series of one hundred and fifty cases found the symptoms established in 96 per cent. Other observers (Riley and Vaughn) found it present in only 46 per cent. and 40 per cent. respectively. The critical observer with a loupe may discover a quick response to light while the average observer will not discover such effect; moreover, the patient on having his eye suddenly uncovered may exert his accommodation and this is met with response of pupil in all cases, so that the discrepancy in percentages is easily accounted for. *Unilateral* Argyll-Robertson pupil is very rare. Berger found it present in three cases out of one hundred and nine tabetics and Gowers once in seventy-two cases. Dercum found four cases among thirty tabetics. For the reason that monocular miosis is very rare in tabes while it is the rule in paresis we have valuable data in differentiating these diseases. (See *Tabes* in this section.)

Argyll-Robertson pupil, Monocular, due to orbital injury. Hirschberg, of Berlin (*Centr. f. prak. Augenh.*, July, 1907), reports the case of a healthy young man in whose left orbit a piece of steel had entered by passing through the lower eyelid and under the left eyeball. This foreign body was successfully removed by the aid of magnet attraction. The wound healed perfectly and the ocular movements gradually returned to normal excepting the outward. The pupil was contracted and did not react to light either directly or consensually, but there was a prompt further contraction to convergence effort. The pupil of the right eye was normal to all reaction tests. This case proves that it is impossible to maintain that unilateral Argyll-Robertson pupil must invariably have a cerebral or spinal cause. In this connection, Velter (*Arch. d'Opht.*, V. 33, p. 120), reports the case of a man aged 58 who, attempting suicide, fired two bullets which lodged in his right orbit against the inner wall. He presented a typical Argyll-Robertson pupil in this eye proving, as in Hirschberg's case, that this phenomenon of the pupil can exist from causes other than syphilis or cerebral disease. Mees (*Münch. Med. Woch.*, V. 60, June 3), also reports having observed typical Argyll-Robertson pupils in an alcoholic patient with polyneuritis and epilepsy in whom tabes and syphilis were found to be entirely absent. (See *Sympathetic, wounds of* in this section, also *Argyll-Robertson pupil, cause of.*)

Argyll-Robertson pupils in toxic amblyopia. Gamble (*Ophth. Rec.*, April, 1902, p. 223), reported the case of a man of 43 who had noticed progressive loss of vision for three months prior. He had never had any illness excepting one attack of muscular rheumatism which, however, was of only a few days' duration. There was no history of syphilis and he presented no evidence of systemic disease of any kind. For some years he indulged inordinately in strong drink; ten or twelve glasses of whiskey a day and a few cigars were his usual quota. The optic disks were atrophic on the temple sides and his vision was greatly reduced on account of the central scotoma present. The pupils were contracted and did not respond to light, singly or consensually, but they did respond to convergence and accommodation.

J. B. Loring in discussing the case raised the question whether the Argyll-Robertson pupils were the result of toxic amblyopia or to a degeneration in the spinal cord (tabes) he cited Gowers as having reported twenty-two cases of Argyll-Robertson pupils which presented no evidence whatever of any other degenerative process. In Gowers' group of cases 75 per cent. of them gave a distinct syphilitic history.

Argyll-Robertson pupils, Recovery of light reaction. Among a vast amount of literature bearing on the subject of the Argyll-Robertson pupil which the writer of this article has carefully reviewed, recovery of pupil reaction spontaneous or remedial was noticed in only one instance, the following: Zaun (*Jour. A. M. A.*, March 1, 1913), reports the case of a man aged 32, in whom the Argyll-Robertson phenomenon was well marked and the other symptoms of tabes were well established. A positive Wassermann was obtained. After a course of mercurial inunctions and iodide of potash, followed by an injection of salvarsan which was repeated in ten weeks, the pupils *recovered normal and prompt reaction to light.*

Argyll-Robertson pupil, cause of—(Dunn's theory). John Dunn (*Archives of Ophthalmology*, Sept., 1918, Vol. XLVII, No. 5, p. 469) sets aside the ordinarily accepted theories that the lesion causing the Argyll-Robertson phenomenon is central, either in the brain or spinal cord, and offers the theory that the specific disease is located in the ciliary ganglion and that it so affects the sensory and motor impulses going to and from this ganglionic station as to inhibit their transmission entirely, thereby producing the Argyll-Robertson syndrome. He believes in the ciliary ganglion as the peripheral reflex center for direct sensory and light reaction as mentioned in this section. (See *Ciliary ganglion,* etc.) He states "Sensations picked up by the short ciliary nerves are carried backwards to the ciliary ganglion. Why to the ganglion? This is the crux of the whole question. The ganglion is not a purposeless mass of nervous tissue. It has a definite function. What is it? Why is it that the motor fibers, the sensory fibers, and the sympathetic fibers that enter it do not pass with their forms unaltered through the ganglion? Why do all three sets of fibers make connections with each other within the ganglion? There can be but one answer—and that is that it is to make possible the existence of primary reflexes; in the case of the ciliary ganglion, these reflexes are manifested in movements of the pupil and ciliary body and in changes in the activities of the ciliary gland. Primary reflexes are brought about wherever there exist extracerebral ganglia. The jerk of the foot when the patella is struck is a reflex response, and to explain it we do not say the nervous pathway is via sensory nerves to the spinal cord, along the sensory spinal nerves to the cerebral cortex, etc. We are satisfied to say that the knee-jerk is mediated through the appropriate spinal ganglia. This reflex belongs to the domain of the voluntary muscles. The primary pupillary response belongs to the domain of the autonomic system. Or, look at the question another way, the sensory elements of the short ciliary nerves convey sensory impressions born in the iridociliary region to the ciliary ganglion. These impressions must serve a physiological purpose within the ganglion, otherwise the ganglion would be unnecessary. The finer ganglionic anatomy is such as to render it certain that these sensory impressions are transmitted to both the ciliary and iritic motor fibers within the ganglia. Then what happens? Motor fibers do not transmit impulses centralwards. The impulses then must be transmitted peripheralwards and can have but one effect, contraction of the sphincter pupillæ and of the ciliary muscle. The sensory impulses from the iridic and ciliary region, which on reaching the ciliary ganglion are therein communicated to the sympathetic element, are transmitted also peripheralwards and result in a response on the part of both the activities of the ciliary glands and of the dilatator pupillæ. If these statements are not so, what is the purpose of the ciliary ganglion? I can conceive of no reason why the motor fibers to the iris and ciliary muscle should be interrupted by a peripheral ganglion other than that thereby is rendered possible the production of primary reflexes, i. e., those reflexes that are produced without recourse to the higher nervous centers. The long and short ciliary nerves are distributed to the ciliary and iritic regions. No sensory nerves have been demonstrated as going from the retina. With an intact iris and ciliary body, if the retina be entirely atrophied, it is impossible to produce the primary light reflex. This proves beyond question that an active retina is a *sine qua non* for the production of the primary light reflex. The retina has distributed to it no sensory nerve terminals from the ciliary ganglia. We might, at first thought, then exclude the possibility of the ciliary ganglion mediating the primary light reflex as claimed above. When, however, light falls on the retinal ganglion cells, great activity is aroused in the adjacent pigment cell layer. This layer is continuous to and through the ciliary and iritic regions, and it is through disturbance of this pigment layer that the sensory nerves of this latter region are stimulated for the originating of the primary light reflex. The motor cells to the ciliary muscle also pass through the ciliary ganglion. This has also for its purpose the making possible of a primary ciliary muscle reflex. This is also possibly secondary to the impact of light in the retina, just as is the primary pupillary reflex, and has for its object a reflex contraction of the ciliary muscle occurring at the same time with that of the contraction of the pupil. It is more likely, however, that the primary ciliary reflex is secondary to the iritic movements of the primary light reflex. These movements create sensory impressions which are transmitted to the short ciliary nerves, thence outwards along the ciliary motor fibers from the ciliary ganglion to the ciliary muscle. This is also an autonomic reflex and is entirely distinct from the accommodation act. As the primary pupillary reflex is probably protective in its origin, so too is the primary ciliary reflex. This primary ciliary reflex is not possible when there is complete atrophy of the retinal cells, and yet under the same conditions both contraction of the ciliary muscle and its consensual pupillary response are at times possible. Why do the long ciliary nerves not pass through the ciliary ganglion? Because their impulses do not take part in the production of a primary reflex. When the ciliary muscle begins to contract, and thus put in motion the crystalline lens system, a set of sensations is aroused different from those aroused by the impact of light on the retina. It is these sensations that are taken note of by the long ciliary nerve terminals and carried centralwards to inform the brain of the degree of contraction of the ciliary muscle, information which assists in regulation of the accommodative action of the crystalline lens and in accompanying changes in the size of the pupils. This is the origin and explanation of the movement of the pupil in accommodation.''

Dunn claims that for the production of the Argyll-Robertson pupil the syphilitic organism selects for its action the sensori-motor and the sensori-sympathetic connections within the ciliary ganglion. (See *Physiology* and also *Pathology* of the pupil this section.)

Argyll-Robertson pupil, Pathological anatomy of the. (See also *Pathology of the pupil* in this section.) Bach (*Zeit. f. Augenh.*, June, 1906), discusses the theories on this subject and describes his own experiments. He comes to no definite conclusion, but states that: (1) Probably the central grey matter, the corpora quadrigemina and oculomotor centres have nothing to do with the production of the Argyll-Robertson pupil reflex. (2) Affections of the superior brachium may apparently cause reflex fixity of the pupil and it would not seem to be necessary for all the fibres to be affected, but it is not improbable that a partial degeneration of the superior brachium as well as of the pathway from the corpora quadrigemina to the medulla does occur in these cases. (3) Usually the oculomotor nerve and the ciliary ganglion and nerves remain unaffected, and have, therefore, probably nothing to do with the causation of the Argyll-Robertson pupil. (4) In those cases not complicated by visual disturbance the optic nerve is found normal. (5) The investigations of the spinal cord, especially in the cervical region, have given very contradictory results and therefore no conclusions can be drawn from them.

For future investigators he advises that special attention should be paid to the medulla and the paths from the medulla to the corpora quadrigemina and also the tracts from the spinal cord to the cerebrum and from the cerebrum to the medulla.

Wilfred Harris (*Brit. Med. Jour.*, Sept. 29, 1900), states he has met with this form of pupil in tabes, general paralysis, juvenile locomotor ataxia, progressive muscular atrophy, lead poisoning, aortic aneurism, hemiplegia, syphilitic meningitis, ataxic paraplegia and nuclear ophthalmoplegia and states that loss of pupillary contraction to light may be considered an almost certain sign of antecedent syphilis, congenital or acquired. He has encountered the pupillary phenomenon in cases presenting no other signs of disease of the nervous system and found a clear history of syphilis in almost every instance. He thinks it is highly probable that the Argyll-Robertson pupil is due to sclerosis of Meynert's fibers, more particularly those which, by Boyce and others, are found to be uncrossed and which are out of the pathway of the light reflex arc but which are in or close to the posterior longitudinal bundle of the same side; and that this sclerosis may be expressed on one side, thus explaining those occasional cases of unilateral reflex iridoplegia that are encountered. (See *Miosis with pupillary rigidity* in this section.)

Arsenical neuritis. Prior to the introduction of salvarsan, neosalvarsan, atoxyl, cacodylate of sodium and other arsenical salts intravenously injected for the relief or supposed cure of syphilitic affections, arsenical neuritis affecting the nerves supplying the eyes was extremely rare. But within the past five years the literature has been flooded with cases of optic neuritis and blindness of varying degrees after the intravenous injection of the arsenical preparations, especially salvarsan. In the writer's limited practice, he has observed no less than ten cases of this character. In them we find mostly unequal pupils with deformity of contour. There is usually some contraction with loss of light reflex. It is not determinable that the optic neuritis is strictly from arsenical poisoning; on the contrary, nearly all argue that the neuritis is syphilitic, being a recrudescence of a slumbering infection. The appearance of the pupils in these cases is not unlike what we see in such specific affections as tabes, paresis and basilar meningitis, which of themselves may cause abnormal pupils. (See *Salvarsan* in this section.)

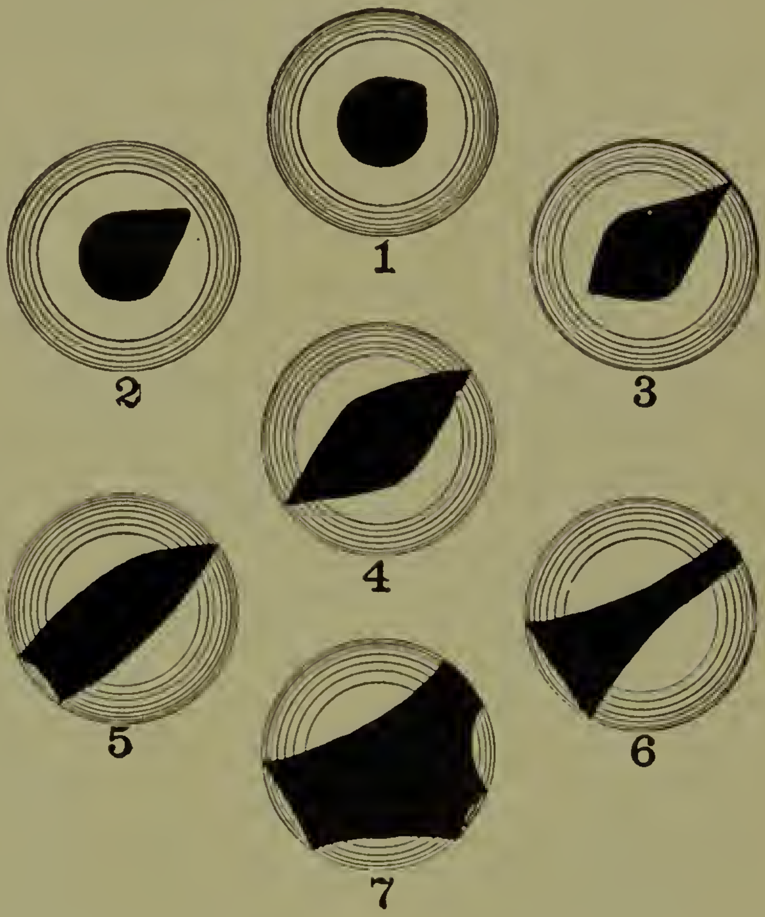
Associated reaction. Comparison between the light reaction and convergence reaction. Laqueur (*Archiv. f. Augenh.*, LIX, p. 527), found that convergence reaction is longer retained and stronger than light reaction. This was proven by observing that convergence reaction remained for a time after the light reaction was lost when homatropin drops were instilled in the eyes, and that convergence reaction returned in advance of light reaction as the effect of the drug wore off. He therefore concludes that the convergence reaction is the strongest stimulus to the pupil that we have.

Moderow (Inaug. Diss., Marburg, 1906), discussing associated pupillary contraction also concludes that the convergence and not the accommodation brings about the contraction of the pupil.

Athetosis, pupillary. Fromaget (*Archiv. d'ophtal.,* XXVI, p. 230), finds an analogy between unilateral hippus due to congenital nuclear palsy which he calls "pupillary athetosis" and the posthemiplegic athetosis of Hammond. The athetosis of the pupil manifests itself through the clinical symptom of hippus. In this connection he also regards nystagmus to be an athetosis of the external eye muscles. (See *Hippus* in this section.)

Atrophy of optic nerves (complete), Normal reaction with. Jessop (*Lancet,* July 11, 1891, p. 73), reported a case of bilateral atrophy of the optic disks and total blindness with retained and intact pupillary reaction to light, but Knies explains this by stating that the ophthalmoscope sometimes shows atrophy of the optic disks with good vision present and that Jessop's case may have had a disorder of the visual areas of the cortex superadded. (See Knies' *text book,* p. 66.) Jessop's case is often referred to by writers as being a case in illustration of the possibility of complete atrophy of the visual fibers of the retina with retained normal function of the pupillomotor fibers. Other cases of like nature have been reported. In one instance, the pupils continued to react to light for four years after complete atrophy of the optic nerve and blindness. (See also *Chiasm* in this section.) Swansy referring to Jessop's case states it is possible that there were symmetrical lesions of the visual areas of the cortex causing "double homonymous hemianopsia." (See also *Cortical blindness—Graefe's reaction* in this section.)

Atrophy, Progressive primary, and disappearance of the iris, or *essential irideremia.* Casey A. Wood (*Ophthalmoscope,* Dec., 1910), reported a rare case of disintegration and resorption of the iris in the right eye of a literary man forty-four years of age, whose history was negative as to bodily disease, but who had sustained a fracture of the right superior maxilla extending into the orbit during a football game sixteen years before. At the time Wood first saw him he was suffering from acute empyema of the right maxillary antrum, which condition was speedily cured by irrigation and drainage. The eyeball presented no evidence of disease of any kind aside from the peculiar change in the right pupil which had progressed as indicated in the accompanying figure until the time he first presented himself to Wood when the iris was observed to have nearly five-sixths disappeared. Mydriatics and myotics were used to determine their effect on the pupil and they induced no change whatever. The tension was likewise unaffected by their use. There was slight response of the nasal iris remnant to light but this soon disappeared. The pigment layer of the iris was not disturbed excepting a slight absorption at the pupillary edge. Glaucoma supervened as an after-incident, due, it was found by microscopic examination, to complete

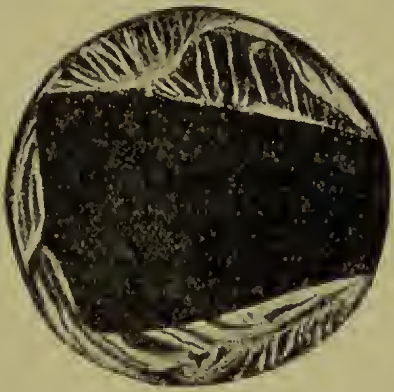


Illustrating Casey A. Wood's case of Primary Atrophy of Iris; the drawings and the dates according to the memory of the patient. 1.—March, 1904; 2.—October, 1904; 3.—February, 1905; 4.—November, 1905; 5.—May, 1906; 6.—December, 1906; 7.—June, 1907.

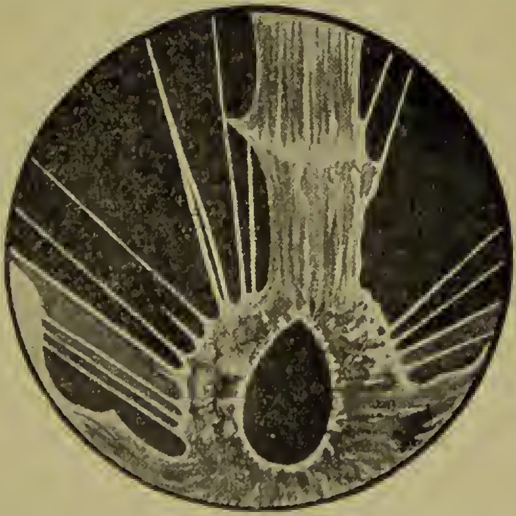
clogging of the pectinated spaces by fibrous exudate and dead tissue-cells. The eye was enucleated as a relief measure for inveterate glaucoma.

In this connection Wood mentions the case of Harms (*Klin. Monats. f. Augenh.*, Nov., Dec., 1903), in which there was unilateral atrophy of the iris and corectopia with no history of trauma. The iris and pupil presenting the appearance indicated in the Fig. Glaucoma supervened in Harms' case likewise; no cause was ascribed. (See de Schweinitz's case report on *Essential irideremia,* in this section.)

Atropin and eserin, Combined action of. Kangieser (Knapp's *Archiv. of Ophth.,* Vol. XL, No. 20, p. 206), studied the effect on the pupil produced by a solution composed of equal parts 1-1000 atropin and 1-1000 eserin dropped in the conjunctival sac. The result was that the quicker-acting eserin caused a contraction of the pupil at first which, however, soon gave way to the more powerful atropin resulting in dilatation. This dilatation was not so marked as when atropin in same strength was used alone. A drop of 1 per cent. eserin solution was instilled into an eye a half-hour after a drop of 1-1000 atropin had been used, the effect was to check the full effect of the atropin. A drop of 1-2000 atropin was instilled at the height of the effect produced by a 1 to 1,000 eserin and the result was a great dilatation of the pupil.

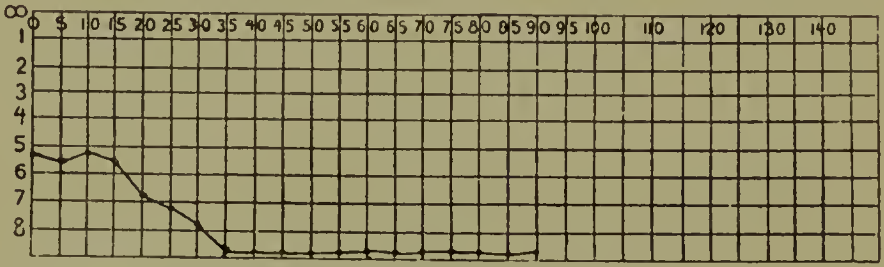


(Continuation of preceding figure.)
Shows (January, 1909) Additional Atrophy of the Iris Stroma.
Pigment layer still intact. Remainder of iris unchanged.

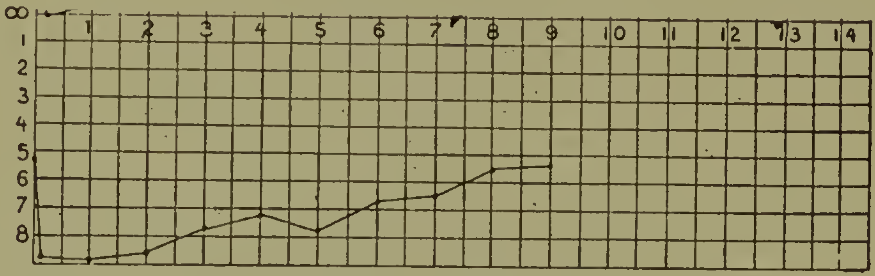


Unilateral Spontaneous Atrophy of the Iris, as Described by Harms.

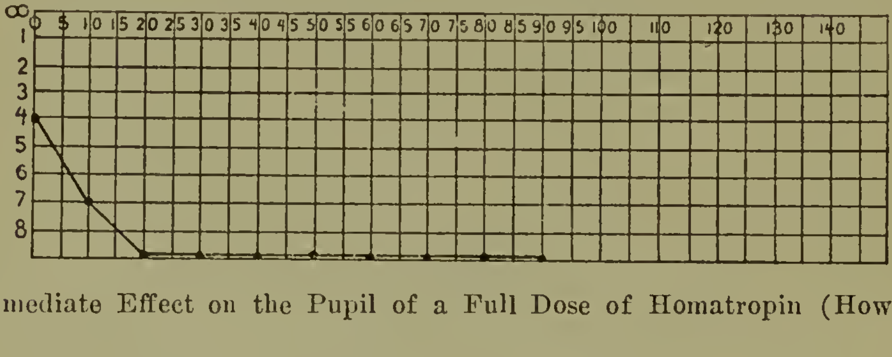
Atropin, Minimum amount of to dilate the pupil. Howe (*Ophthalmology*, July, 1906, Vol. II, No. 4, p. 623), defines mydriasis as being that state of the pupil in the adult in which we note the diameter measures more than seven mm. He estimates that 0.000005 gram of atropin is the smallest amount that will produce dilatation of the pupil in the average healthy adult. Arteriosclerosis so common among adults will inhibit the action of mydriatics.



Immediate Effect of a Full Dose of Atropin. (Howe.)
In this, and in all similar diagrams of this group, the numbers reading downward represent millimeters to show the diameter of the pupil.



Effect on the Pupil for Nine Days After Full Dose of Atropin (Howe).

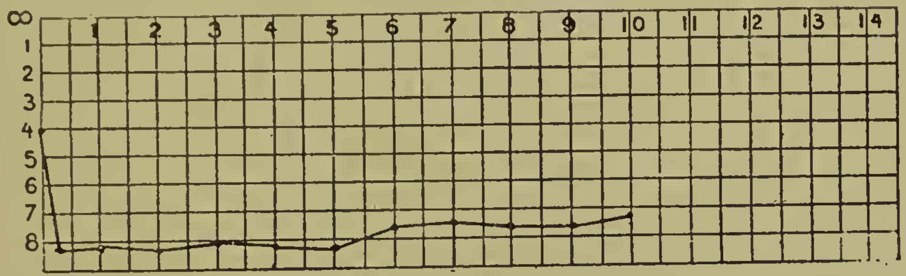


Immediate Effect on the Pupil of a Full Dose of Homatropin (Howe).

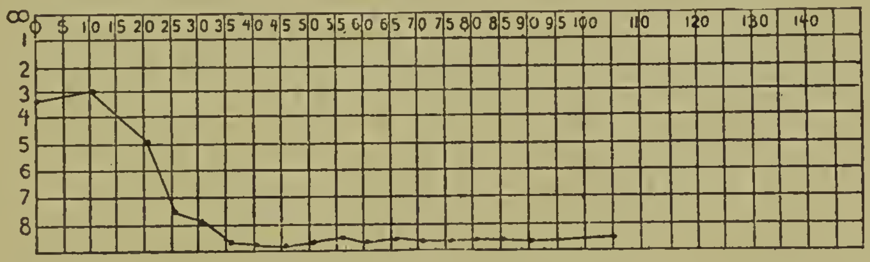
Donders states that if 1 to 120,000 solution of atropin sulphate is kept long enough in contact with the cornea it will dilate the pupil. Fedderson found that 0.000002 gram of atropin dilated the pupil in every case.

Howe after comparative studies of the effects of atropin and homatropin comes to the conclusion that as a mydriatic homatropin is infinitely the better of the two. He advocates the use of the gelatin disks 1/500 grain each.

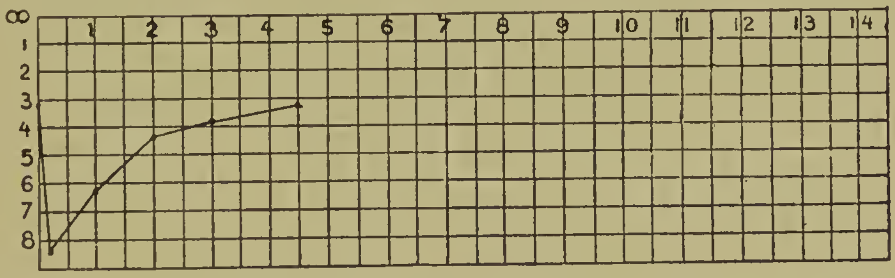
Atropin effect on the lens as observed after iridectomy. Atropin will dilate the pupil but not disclose the lens margin. The latter can be seen when iridectomy has been performed, after which, according to Hess, atropin causes minute elevations and depressions in the contour of the lens margin while eserin does not cause such phenomena.



Effect on the Pupil Ten Hours After a Full Dose of Homatropin (Howe).



Immediate Effect on the Pupil of a Minimum Dose of Atropin on a Young Subject (Howe).



Effect on the Pupil Four and a Half Days After a Minimum Dose of Atropin (Howe).

Atropin in mydriasis. If the pupil is dilated from paralysis of the sphincter pupillæ from any cause and a mydriatic drug like atropin in solution be instilled, it will dilate still wider. This test has been used by some to argue that atropin and allied drugs have a stimulating effect on the fibers of the dilator pupillæ.

Babinski's test. In the Argyll-Robertson phenomenon, if the eyes are bandaged for half an hour and then the pupils tested with direct light they will sometimes react.

Bach and Meyer's hypothetical pupillary centers in the medulla. Bach and Meyer experimented on cats and demonstrated that double section of the medulla at the spinal end of the fossa rhomboidea immediately produced reflex light paralysis of both pupils, whereas unilateral section only affected the pupil of the opposite side and irritation of the fossa produced miosis.

They explain these phenomena by assuming the presence of inhibitory centers at the spinal end of the fossa. Bach's claims are denied by Trendlenburg and Bumke (*Klin. Monats. f. Augenheilk.*, 45, 1907, p. 353), who in order to prove or disprove the existence of pupil controlling center or centers in the medulla, as claimed by Bach and Meyer, conducted extensive experiments on cats carefully cutting one-half the medulla and watching the effect on the pupil. Summarizing their results: considerable loss of blood causes mydriasis, etherization produces reflex iridoplegia, exposure of the medulla does not cause anything of the kind; therefore, they state, the pupillary disturbances observed by Bach and Meyer in etherized cats were due to the anesthetic alone. The mydriasis noted on cutting the medulla differed in no respect from that produced by any other intense sensory excitation (sensory reflex dilatation).

In all cases of hemisection of the medulla the pupil became miotic although in some cases it was for a short period slightly dilated previously to contraction. The same observation was made when the section was through half the cord lower down. After cutting the rhomboid fossa or exposing it miosis or sluggish reaction to light never occurred, thus disapproving any casual relation between the rhomboid fossa and pupillary behavior. From these observations and others Bumke states it is without prospect of success to search further in the medulla for pupillary centers or the anatomo-pathologic causes of reflex iridoplegia. (See *Centers of inhibition* in this section.)

Balance mydriasis. Frenkel (*Arch. med. de Toul.*, October 15 and November 1, 1904), denominates the oscillating dilatation of the pupil that follows a spasm of the dilator pupillæ as *mydriasis a bascule* (balance mydriasis). It is not a pathognomonic sign of paresis as others have pointed out for it may occur in other less grave diseases, as tabes, neurasthenia, phthisis, etc.

Basedow's disease, Latent inequality of the pupils in. Cantonnet (*Soc. de Neurolog de Paris,* July 1, 1909), employed a refinement in diagnosis in six cases of Basedow's disease, finding that while the pupils were equal in ordinary light there was a difference in size noted in semi-darkness. It is conceivable that this test, which is not commonly known, may be of distinct value in the diagnosis of many incipient diseases of the cerebro-spinal axis, as well as in Basedow's disease.

Bibliography. The student is referred to the citations given by A. J. Ballantyne in his comprehensive review on the "Diagnostic Significance of the Pupil and its Reflexes" (*Ophthalmoscope,* July and August, 1909), comprising sixty-one references, together with those from C. B. Walker's masterful contribution on the "Topical Diagnostic Value of the Hemiopic Pupillary Reaction and the Wilbrand Hemianoptic Prism Phenomenon" (*Trans. Ophthal. Section A. M. A.* 1913), comprising eighty-three additional references. These references indicate many, though by no means all, of the valuable contributions on the subject of the pupil in health and disease.

The student is also referred to Prof. Ludwig Bach's work on *"A Study of the Pupils"*—the Physiology and Pathology and Methods of Examination (S. Karger, Berlin) wherein will be found a bibliography comprising 1778 citations.

Bird's pupils, Size and shape of. Casey A. Wood (*Ophthalmology,* April, 1907, Vol. III, No. 3, p. 381) states the size and shape of the pupils in birds are closely related to the focussing apparatus. The motility of the iris and pupil is most remarkable. In some birds, e. g., the yellow-eyed parrot, the pupil seems to be under the control of the will. In the majority of birds the pupils are round, but in some nocturnal birds, like the owl, those which are round when dilated will contract to a vertical slit. The owl's pupils respond to light quite as uniformly as our own.

Wood also demonstrated consensual reaction of the pupils in owls. (For a full account of the pupils in birds, etc., see pp. 2634-2639, Vol. IV, of this *Encyclopedia.*)

Behr's pupillary sign. Dilatation of the pupil on the side opposite to the affected eye, as when the nasal field in one eye is affected. (See *Physiology and pathology of pupillary reflexes,* by Behr, in this section.)

Brachial plexus, Paralysis of the. The rami communicantes of the first dorsal roots of the spinal nerves may be paralyzed and give rise to symptoms referable to the cervical sympathetic. There are two types of disease of this kind, first, the so-called Duchenne-Erb, or upper form, in which the fifth and sixth cervical roots are involved, and in which the pupils are not apt to show any abnormality; and second, the Klumpke or lower form in which the eighth cervical and first dorsal roots are implicated. This type of brachial plexus palsy always affects the rami communicans if the roots are involved, and the consequence is, paralysis of the cervical sympathetic supplying the dilator pupillæ. In this latter type we find the classical Horner's syndrome present; viz., miosis, partial ptosis, enophthalmos, etc. (See *Horner's syndrome*, this section.)

Brain tumors, The value of the pupil in diagnosing. If the tumor is located above the tentorium or in the frontal or silent areas of the brain the pupil will not show abnormality that leads to a diagnosis; but if the tumor is below the tentorium, causing pressure under that resisting partition, there will be hydrops of the ventricles and almost certain paralysis of the filaments of the third nerve disturbing the pupillary reflex arc causing mydriasis.

Casper has observed that when the lesion is located in or near the third ventricle there is anisocoria and hippus, but if the lesion is between the external geniculate bodies at the sphincter nucleus the Argyll-Robertson phenomenon is present (Uhthoff).

The presence of nystagmus in association with dilated pupils fixes the suspicion of the tumor being in the cerebellar fossa. The location of a brain tumor cannot be determined by any pupillary tests for there is no definite or uniform behavior of the pupils in brain tumors. The pupillary reactions studied in conjunction with other symptoms often lead to a correct localization. (See *Diagnosis* in this section.)

Brown-Sequard paralysis. G. W. Hall (*Ann. Ophthal.,* July 1913, p. 575) reports a case of Brown-Sequard paralysis showing ocular symptoms of involvement of the sympathetic nerve. There was an indefinite history of syphilis. The attack came on suddenly. The patient became paralyzed on the left side with complete loss of sensation. The ocular symptoms were marked ptosis of the right upper eyelid, enophthalmos and marked miosis. The lesion was located in the lower cervical and first dorsal portion of the spinal cord, resulting in complete paralysis of the cervical sympathetic on the right side. Improvement set in after a course of specific treatment. Hall further mentioned (*idem,* p. 579) another case of like nature presenting the Brown-Sequard syndrome from unquestionable lesion of the cord in the region of the cilio-spinal center which he presented before the Chicago Neurological Society in 1911. He also described two other cases of *cervical rib* in each of which there was involvement of the sympathetic nerves and consequent miosis from pressure of the aberrant rib. After the operation of removal of the cervical rib the miosis nearly entirely disappeared. (See *Rib, cervical.*)

Budge's center. Budge's cilio-spinal center exists in the spinal cord in a region between the sixth cervical and fourth dorsal nerves probably opposite the eighth cervical and first dorsal.

Bulbar apoplexy, Acute. Acute bulbar apoplexy proclaims itself in unmistakable clinical signs, as described by Dana; coma, facial twitchings, irregular pulse, Cheyne-Stokes respiration and *contracted pupils* are the classical signs of the disease at its onset.

The contracted pupils are evidently caused by paralysis of the dilator pupillæ center located in the medulla. Contraction of the pupil also occurs in bulbo-pontine softening from the same cause, i. e., involvement of the sympathetic or dilator pupillæ center mentioned. The condition of the pupils becomes a valuable aid in differentiating pseudo-bulbar paralysis and myasthenia gravis in which a very similar group of symptoms are exhibited though much slower in manifesting. In the latter disease the pupils are usually unaffected.

Bumke's test in blindness from tabes. If a blind tabetic be asked to fix his attention on an imaginary distant object and then on an object in his hand the pupils may contract, thus proving intact association between centers for convergence and the sphincter pupillæ.

Cardiopathies, mitral, Pupil reflexes in. Braillon (*Gaz. d. Hôpitaux,* June, 27, 1906) states that the pupillary immobility to light in patients suffering from aortic disease apparently apart from any affection of the nervous system, has become a clinical commonplace. This phenomenon is not, however, to be regarded as a relation between cause and effect but as a part of a syndrome of one and the same disease, viz., syphilis acting on the aortic and the central nervous system at the same time. (Babinsky.)

Braillon now raises the question whether the investigation of the pupillary reflexes will afford information as to the cause of certain cases of chronic endocarditis. He believes from cases he has studied, that iridoplegia associated with mitral disease declares that the latter is not to be ascribed to so-called "rheumatic" influences but to syphilitic disease, thus establishing a parallel between the cases of pupil rigidly associated with aortic and those associated with valvular cardiac disease. (See also *Aortic aneurism* in this section.)

Cataract, The pupil in. All kinds of cataract must be diagnosed through the pupil. The color of the pupil may be changed according to the location and kind of cataract present. It is well known that the normal pupil responds to the light in cases of senile cataract quite as well as if no cataract were present. The single exception is in the case of black cataract. The writer has seen a case of black cataract in which the pupils were dilated and fixed. No red reflex was obtainable and yet after the cataracts were removed the vision was restored to 20/20 and the pupil response after operation was prompt and normal.

If the pupil in senile cataract does not dilate at least half-way with one drop of a 2 per cent. homatropin, or 6 per cent. euphthalmin, it shows that the patient probably has high blood pressure and arteriosclerosis of the eye.

Lieut. Col. Henry Smith, of Amritzer, India, attaches great importance to the size and behavior of the pupil in determining the operability of cataract. If the pupil responds normally he will operate with every assurance of success as regards restored vision.

Bach states that cataract, uncomplicated, senile, does not affect the pupillary width or the light reaction as a rule. In the stage of swelling the iris may react a little slowly and the pupil be slightly larger than its fellow, or the reverse may be true. (See *Mydriatics and myotics in cataract operation* in this section.)

Cat-like pupils in man. In Knapp's *Archives of Ophthalmology,* (Vol. XLIII, No. 2, March 1914) appears an illustrated article written by Greeff, of Berlin, describing the following cases of cat-like pupils in man. Four of the cases had come under his own observation and a research through literature enabled him to find but two more.

Case I, by Fehr: The illustration (see fig.) shows a vertical pupil in the left eye. The right shows a horizontal pupil similar to the horse's eye. In subdued light the pupil is oval, but upon strong illumination it takes the form of a narrow slit.

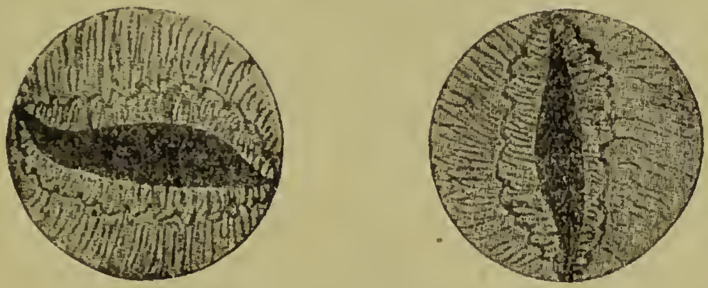
Case II, by Burstenbender: A three months' old baby presented a vertical left pupil a little to the nasal side. (See fig.) The right pupil in this case likewise presented a horizontal slit like in the eye of a horse.

Case III, by Greeff: The right pupil extends vertically, has a very narrow slit and responds very little on account of posterior synechia. The left pupil is likewise vertical and a little to the temple side of the middle.

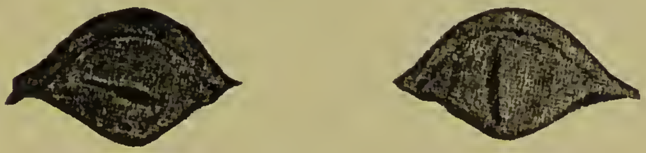
Case IV, by Greeff: A girl of ten, the pupil of the right eye was slit-like, but more oval than the above and the extremities did not reach the periphery of the iris. There was slight ectropium uvea. (See plate.) The pupil was obliquely placed. The iris below presented a grayish mass covering its surface.

Case V, by Decking: The right iris had a vertical aperture located in the outer third of its plane. This was surrounded by a well-marked sphincter zone. The left eye presented a slit in the iris running from up and in to down and out. The left iris also had a horizontal slit running at right angles to the vertical as shown in illustration. In none of these cases was the vision anywhere near normal.

In this connection we would like to mention the unpublished case of a women of 26, in which the left pupil was entirely normal. The right presented a slit which ran across the iris plane a little above the center. This slit contracted in the light so that it was a mere line, and in darkness it opened so that it was slightly fusiform. The vision in this eye with correction was entirely normal. The eye was full sized. In Greeff's cases and those reported, the pupils became round or nearly so in the dark. Fehr maintains that these pupils present the same anatomical structure as the eye of a cat. Instead of forming a ring around the pupil the sphincter of the iris radiates from the pupil margin towards the periphery. He states that the sharp ends of the slit-like pupil and the regulating of the sphincter zone are positive evidence that these are not anomalies due to coloboma. In certain birds of prey, the brown owl, some species of snakes and the crocodile there is a vertical, slit-like pupil. In all these the pupils are large and round in the dark and become slit-like in the light. There are some theories discussed as to nature's intentions in making the pupil slit-like in cats and other species. He believes that a round pupil would accomplish the same purposes.



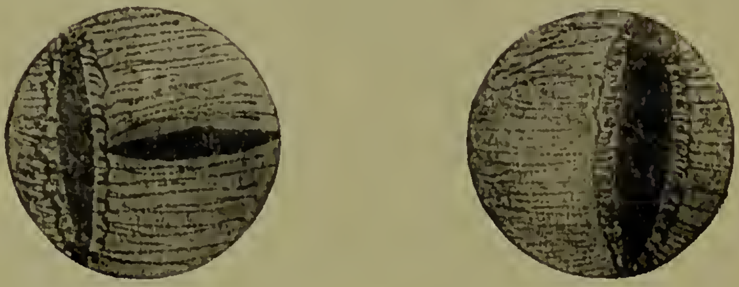
Catlike Pupils in Man. Fehr.



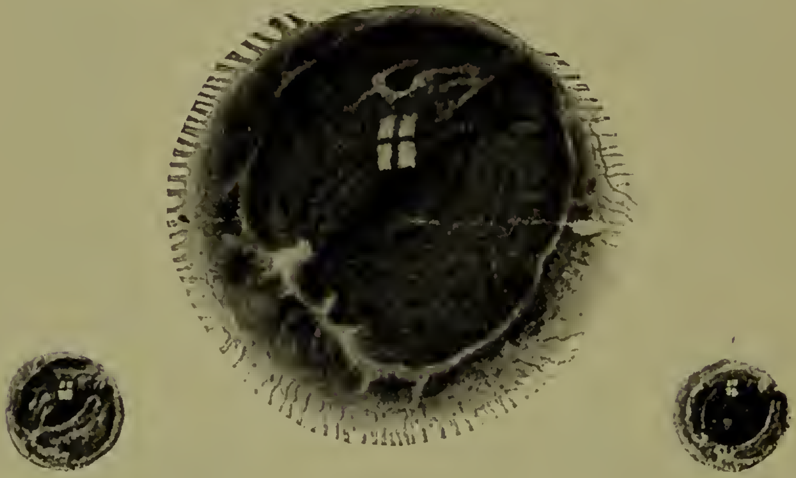
Catlike Pupils in Man. Bürstenbinder.
(Left Eye) (Right Eye)

Wolfskehl, Matthiessen and others have expressed the opinion that such eyes have a high degree of astigmatism and the stenopaic pupil gives a sharp acuity. Experiments on cats' eyes have not found this to be the case. Fehr argues that these cat-like pupils in man are an expression of retrogradation of the eyes toward a former stage of evolution (atavism). There is no doubt that the condition is congenital. Such eyes are not accidents.

In discussing the vertical and horizontal pupils in cats and horses, the opinion may be ventured that it was nature's plan to permit the cat, which in a wild state lives in trees, to have an extended vertical field, while the horse, which lives on the ground has need of an extended horizontal field. These differences in the direction of the slits are to be taken as an expression of nature's effort for preservation of the species.



Catlike Pupils in Man. "Case 4."



Undilated. Enlarged. Dilated.

Catlike Pupils in Man. Decking.

Cat-eye refulgence. Santos Fernandes (*Cron. Med. Quir de la Habana,* V, 40, p. 197) reports an interesting case of acquired red shine in the pupil of a healthy man who, he believes, had anemia of the retina as a consequence of a prolonged visitation to the tropics. The pupils of his eyes would emit a striking red reflex noticeable in the bright light as well as in a darkened room. (See *Red shine* in this section.)

Centers of inhibition for light reflex and dilatation. Bach and Meyer (*Archiv. of Ophthal.,* Vol. LV and LVI) experimenting on lower animals claim that they have proven the existence of an inhibition center for the light reflex and also an inhibition center for pupillary dilatation in the upper part of the spinal cord and the lower part of the fourth ventricle near the median line. Irritation of this part always produced pupil rigidity and miosis. Irritation of the center on the right side produced rigidity of the left pupil. Bach explained the miosis present in this experiment by stating that the more powerful sphincter muscle of the iris acting unopposed results in fixed miosis. Reichardt (*Arch. f. Psych. u. Nervenkr.,* Vol. XXXIX, No. 1) found degeneration of endogenous fibers in the second and third cervical segments of the cord in the area between the posterior commissure and the ventral part of the column of Goll (the so-called Bechterew's intermediate zone) in a series of cases of tabes and paresis. These patients all presented rigid contracted pupils. He assumes from laboratory studies of sections of the upper part of the spinal cord in these cases that there are four pupillary areas in the cervical cord.

1st. Budge's center (cilio-spinal center). 2nd. A pupillo-dilator center in the upper part of the cervical cord. 3rd. An inhibitory center in this region for light reflex. 4th. A center for dilatation of the pupil from sensory irritation of the skin of the neck.

He believes that psychical and sensory stimuli keep the pupils in a state of unrest when influenced by these centers in contention with the pupillary contraction impulses. Pupillary contraction and rigidity results when these centers are destroyed as in tabes, some cases of paresis, profound traumatism, and syringomelia affecting the area lying between the upper dorsal segment of the cord and the medulla. (See *Bach and Meyer's hypothetical centers,* also *Motoroculi nucleus.*)

Centripetal and centrifugal fibers. The centripetal fibers of the pupillary light reflex arc have their origin in the retina, the end organs being more abundantly disposed in the region of the macula lutea and disposed in a less abundant manner as they approach the periphery of the retina. In this arrangement they simulate the distribution of the end organs of the visual fibers of the retina. They accompany the visual fibers on their way to the brain, those originating in the nasal side of the retina crossing over in the optic chiasm to the other cerebral hemisphere, while those originating in the temple side of the retina pass on to the cerebral hemisphere on the same side without crossing. They are the coarse fibers noted and described by von Gudden, von Monakow and others. (See *Physiology of the pupil.*)

"When they reach the brain, according to Bernheim, they bend inward, pass to the anterior part of the anterior corpora quadrigemina and thence to the sphincter nucleus in the anterior portion of the nucleus of the third nerve." (Weeks in Posey and Spiller on *The Eye and Nervous System*, p. 291.)

There is some dispute about these fibers entering the corpora quadrigemina. Experiments on monkeys by Ferrier and Turner (*Brain*, 1901, Vol. XXIV, p. 27) showed the pupil reaction was not abolished after the corpora quadrigemina were destroyed, but when the underlying gray matter of the aqueduct of Sylvius was destroyed the pupil no longer reacted.

Bechterew (*Arch. f. w. ges. Physiology*, XXXI, s. 60) experimenting on dogs made the following observations:

(1) Destroying the sphincter nucleus in one side of the brain caused loss of direct light reflex in the eye on the same side and loss of consensual reaction to the fellow eye.

(2) A lesion of one side of the third ventricle caused loss of pupil reaction on the same side but did not affect the vision.

(3) A lesion of both sides of the third ventricle caused loss of pupil reaction in both eyes and did not affect the vision.

"The centrifugal fibers of the pupillary light reflex are arise from the sphincter nucleus, pass into the underlying tissue of the pons where they are joined by fibers from the ciliary nucleus. They then pass into the trunk of the third nerve occupying, according to Ackerman, the central part of this nerve trunk; then by the short root of the ciliary ganglion, then by the short ciliary nerves (five to seven in number) to the posterior part of the globe, passing through the sclera and forward between choroid and sclera into the ciliary body; from the anterior posterior of which they pass into the iris tissue and to the sphincter." (Weeks, *l. c.*)

(For illustrations showing the pathways of the centripetal and centrifugal pupillary fibers see *General considerations* in the introduction to this section.)

Cerebro-spinal meningitis. Ballantyne (*Brit. Med. Jour.*, July, 1907) investigated the ocular signs in this disease among seventy-three cases. The pupils were unequal in eighteen cases. They were dilated in thirty-four and contracted in five cases. Hippus was present in thirty-one cases. While the pupils in this disease present no constant behavior they usually show abnormality which fact considered along with other symptoms, becomes of much value in determining the diagnosis and prognosis.

Changing pupil. Erlenmeyer (*Berl. klin. Wochensch.*, 1912, p. 539) saw bizarre behavior of the pupils in a woman of forty-eight. They continued to change their forms; sometimes they were round, at other times oval and still other times dumb-bell shaped with intermediate forms. The pupils also assumed amœba-like movements at times. The case was one of hysteria which was proven definitely by other tests.

Coppez (*Soc. Belge d'ophtal.,* November 27, 1908) reported the case of a girl who had mydriasis of one eye which was changed into myosis when her head was bent forward. The myosis was accompanied by severe pain. After the superior cervical ganglion was removed the pain ceased but the paradoxical pupillary contraction persisted.

The patient had mediastinal polyadenitis and Coppez believes that inclining the head caused the enlarged glands to press on the cervical sympathetic thus causing the pupillary change. (See *Cyclic contraction and dilatation, Wandering pupil, Jumping pupil and See-Saw pupils* in this section.)

Cheyne-Stokes respiration, The pupil in. Byrd, of Tampa (*Ophthalmology,* April, 1915, Vol. XI, No. 3, p. 517) reports the case of a man of twenty-one, who after an injury developed Cheyne-Stokes respiration. He noticed that at times the pupil was dilated and other times contracted. The patient was thoroughly unconscious. On studying the case he discovered that there was a relation between the pupil behavior and the respiration. The pupil did not respond to light, but when the patient had the slow, labored phase of breathing the pupils began to dilate, reaching a diameter of 6 mm. As the respirations quickened the pupils became contracted and when the respirations ceased they were only 1 mm. wide.

He explains the phenomena in an ingenious manner by assuming that there was a clot compressing the sympathetic fibers along the walls of the carotids. This pressure was made intermittent by the respiratory act and the blood pressure within the carotid. During the abeyance of the respiration, when the blood pressure was highest, there was great pressure on the nerve fibers between the vessel walls and the clot, causing inhibition of the pupillary dilating mechanism and resulting in contraction; while in the phase of violent inspiratory efforts the carotid blood pressure was reduced, causing the pressure on the fibers between the vessel walls and the clot to be released and thus permitting resumption of the dilating pupillary function.

Chiasm, disease of the. In a case of pituitary tumor affecting the chiasm, reported by Saggel (*Arch. of Ophth.,* January, 1901, Vol. XXX, No. 1, p. 3) the pupils were both equal and contracted normally in spite of the fact that the patient had bitemporal hemianopsia. In cases reported by C. B. Walker (see *Wernicke's test*) the pupils would respond to light even in the presence of blindness, leading him to assume that the pressure on the optic chiasm and optic nerves at the foramen had destroyed the conductivity of the visual fibers leaving the pupillomotor fibers still capable of conducting impulses. In a case which the writer of this section examined recently, the pupil of the right eye, which was entirely blind, showed a slight but unmistakable response to the direct light test.

Chorea, The pupillary signs in. Langmead (*Lancet,* January 18, 1908) made the following observations regarding the pupillary behavior in cases of chorea.

I. *Hippus.* In severe cases of chorea of the sthenic type the movements of the pupils were extraordinarily wide and rapid. He thought the jerky movements of the eyelids which accompanied the hippus was responsible for the bounding pupils.

II. *Abnormal reflex in the presence of unequal pupils.* He noticed the pupils may be unequal in chorea in which case it was observed that the larger contracted more slowly and that there was inharmonious action, one contracting while the other remained dilated.

III. *Miosis.* The contraction of the pupil to light and convergence was unstable; often fatigue was expressed more in one than in the other pupil, so that one would dilate and the other remain contracted.

IV. *Varying inequality of the pupils.* One pupil may remain persistently smaller than the other at one examination and at the next examination the reverse may be observed.

V. *Eccentric pupils are occasionally present.* These bizarre pupils were noted in cases where articular rheumatism accompanied the chorea.

Chorioretinitis. Bach states that in chorioretinitis, involving the macula with considerable loss of central vision, the light reaction is usually feeble.

Choroiditis disseminata. Bach states that in choroiditis disseminata, if the visual acuity is normal, the pupillary reaction is unaffected. In a case of areolar choroiditis, where a large sector of the field was defective, it could be shown that a weak pupillary reaction followed illuminating that area.

Choroiditis, Suppurative. Pichler (*Klin. Mon. f. Aug.,* 54, p. 682) observed in three cases, two of pneumonia and one of septicemia, sudden mydriasis and paralysis of the sphincter pupillæ as the first symptom of an oncoming suppurative choroiditis.

Ciliary processes in the pupillary area. A case reported by Schweigger (*Arch. of Ophth.,* January, 1902, Vol. XXXI, No. 1, p. 24) was

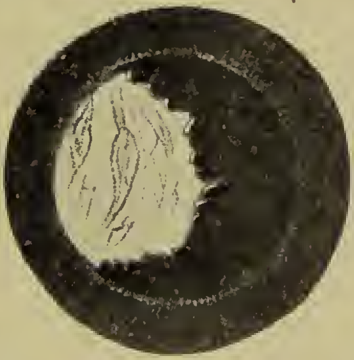
A REFERENCE CHART OF
Pupillary Symptoms of Diseases
By G. GRIFFIN LEWIS, M. D., SYRACUSE, N. Y.

NAME OF DISEASE	Mydriasis	Miosis	Anisocoria	Hippus	Argyll-Robertson Pupil	Sluggishness	Paradoxical Reflex	Miosis followed by Mydriasis	Irregular Outline of Pupil
Acromegaly	+								
Alcoholism	Paretic, bilateral with nuclear disease of motor oculi.		+					+	
Amyotrophic Lateral Sclerosis		If lesion is in cilio-spinal region.	+		+				+
Asphyxia	+							Serious	
Anæmia, cerebral	Paretic								
" general	Spastic, bilateral								
" pernicious			Latter stages						
Aneurism, intracranial			Rarely						
" of the neck	+	Paretic	+						
Aortic regurgitation	Bilateral								
Apoplexy	Paretic	+	+						
Burns, extensive	Bilateral								
Catalepsy	Spastic								
Cerebellar ataxia	Some times				Sometimes				
" tumors				+					
Cerebral abscess	If there is much pressure at base.	Spastic							
" anæmia	Paretic, bilateral								
" apoplexy		Spastic, in early stage							
" concussion		+							
" embolism		Unilateral							
hemorrhage	+	If pontal, cerebellar or ventricular	Often			+			
" hyperæmia		Spastic							
" inflammation		Spastic							
" pressure	Bilateral		+					+	
" syphilis	+		+				+		
" thrombosis	+			+		+			
" tumors		Spastic							
Cerebro spinal sclerosis			+	+	2%	+	+		
Cervical glands, inflammation of			+						
Chloroform poisoning								+	
Chlorosis	+								
Chorea			8%	May be		May be			
Colic, biliary	Spastic								
" lead	Spastic								
Collapse	+								
Coma, diabetic	+					+			
" hysterical	+								
" uræmic	+								
Convulsions, eclamptic	Spastic								
" epileptic	Spastic								
" uræmic	+								
Cord, lesions of		If above the dorsal region							
Delirium, acute	Bilateral	+							
" tremens	+								
Dementia, paralytica	Spastic, in latter stages	In early stages	+	+	8% latter stages.	Early		Usually	+
" senile		+	Sometimes		8%				
Diabetes	Unilateral or bilateral		+						
Diphtheria	As a sequel					+			
Disseminated Sclerosis		Spastic	+	+		+	+		
Drowning	+								
Epilepsy	Spastic	Spastic in beginning	¼ more marked after attack	Towards end of attack and during intervals	7%				
Ether poisoning								+	
Exophthalmic goitre			11%						
Fever, intermittant			+						
Glaucoma	Paretic.		+						
Hemianæsthesia					4%				
Hydrocephalus	+								
Hyperthrophic peripheral neuritis					+				
Hypochondria	+								
Hypnotism	+					+			
Hysteria	Spastic or paretic	Spastic in early stage. Paretic later.			+	+	At times.		
Hystero epilepsy	In latter stages.	In early stages.			7%			+	
Insanity	Premonitory, trancient, alternating.	Premonitory, transient, alternating.							
Intestinal irritation	Spastic, bilateral								
Lead poisoning	+				+				
Lepto-meningitis	In latter stages	In early stages	+	+		Pronounced		+	
Lepto-meningitis, acute spinal	Spastic in early stages.		Sometimes						
Mania, acute	Spastic			+					
Melancholia	Spastic								
Meningeal hemorrhage	Paretic								
Meningitis	Stage of depression	Early		Early stage					
" epidemic cerebro-spinal	In early stage	In latter stage			+	+		+	
" spinal	Spastic, if in cervical portion	If 8th cervical and 1st dorsal regions are involved.				If hypermetrophic			
Myelitis	Usually early	In transverse cervical	Often		Usually				
Narcosis, chloroform or ether		+							
Neuralgia		In unilateral trigeminal or cervico-occipital	In spinal and cerebral						
Neurasthenia	+		Often transiently	+					
Neuritis, localized	+								
multiple		Sometimes	+						
Pachymeningitis			Often						
Paralysis, acute ascending			Occasionally			occasionally			
" facial	+								
" of the cervical sympathetic		Paretic							
" progressive							+		
Pneumonia, tubular			+						
Polyencephalitis hemorrhagica					+				
Polyneuritis, alcoholica					+				
Pontal hemorrhage		Paretic if in upper part							
Posterior spinal sclerosis	Premonitory. Spastic. Paretic in latter stages.	In latter stages	+		Most constant symptoms		+		+
Progressive muscular atrophy		Unilateral or bilateral, if in cilio-spinal region			+				
Ptomaine poisoning	Spastic								
Rectal irritation	+								
Shock	Bilateral								
Spinal apoplexy		In transverse cervical			If lesion is in cilio-spinal region				
" caries			In cervical lesions						
" hyperæmia	Spastic								
" sclerosis		Paretic		+					
Syncope	Bilateral								
Syringamyelia		+	25%						
Teeth, diseases of			+						
Tetany	Spastic								
Tuberculosis, pulmonary	Early		+						
Tumors of the cord	Spastic								
" " neck	In latter stages		+						
" " 3rd nerve		+							
Typhoid fever		+							
Typhus fever				+					
Uræmia	+								
Urticaria	Bilateral								

+ Indicates the presence of the symptoms under which it occurs.

that of a man of twenty-two, who had a congenital cataract and microphthalmos in one eye and nystagmus of the other. In the cataractous eye, under a mydriatic, he demonstrated about twenty-five ciliary processes which occupied more than half of the pupillary margin. (See fig.) Another case in the same reference (p. 27), reported by Fisher, of London, was that of a girl of four who had a shrunken opaque lens in the right eye in which the pupil was slightly displaced. The cataract present was drawn to one side by adhesion with the ciliary and upon dilating the pupil with atropin there was a series of finger-like processes which were unmistakably the ciliary processes numbering from 12 to 20.

Ciliary ganglion as the peripheral center of the pupillary reflex. Mariana (Internat. Cong. Budapest, 1909) from his experiments on monkeys which consisted in transplanting the external rectus to take the place of the internal rectus, *et vice versa,* in which it was noted that the pupil contracted on convergence, and from observations of pupil reaction in convergence among tabetics presenting Argyll-Robertson pupils, concludes that it is quite possible that the ciliary ganglion is the peripheral center for pupillary reflex contraction and that the inward rotation of the eyeball stimulates the sphincter to contract because the short ciliary nerves are stretched. This hypothesis would tend to prove why the pupil contracts when the eyeball is grasped with forceps and against the patient's will is made to converge toward the nose. (See *Convergence and contraction,* also *Sympathetic roots* in this section. See also *Argyll-Robertson pupil, cause of,* in this section.)



Ciliary Processes in the Pupillary Area. Schweigger's Case.

Cocain action—diagnostic value. Henderson and Parsons (*Ophthal. Rev.,* November, 1908) experimenting on rabbits proved the action of cocain in dilating the pupil to be due to stimulation of the sympathetic nerve fibers in the iris. The left cervical sympathetic was removed. The next day both pupils reacted to light, the right measuring

8 mm. and the left 5 mm. Repeated instillations of cocain drops caused the right pupil to dilate to 11 mm. but produced no effect on the left. (See *Mydriatics and Myotics* in this section.)

Coloboma of the iris, Congenital. In cases of congenital coloboma the pupil assumes a pear-shape if there is present an appreciable apron of iris at the periphery of the coloboma, or U-shape if the actual gap runs quite to the periphery. In the latter case the ciliary body, the suspensory ligament of the lens and in some instances the choroid and retina also present colobomata, all being in the same general antero-posterior pathway and representing the delayed closure of the ocular cleft in the embryo. Thus the location of the cleft in the iris is usually down and in, although some cases present the anomaly downward and others down and out. The condition is apt to be bilateral, although in some cases is only unilateral. Associated with complete coloboma of the iris are very often found microphthalmus and congenital cataract. The cornea is usually small, the anterior chamber deep and the pupil seems actually displaced downwards and inwards. The condition closely simulates the appearance of the pupil seen after an iridectomy operation, but on close inspection it is easily found that no operation has been performed, for the uveal pigment is traced around the edges of the coloboma in a way that is never seen after operation. Moreover the cryptic markings of the lesser circle of the iris shows a gradual decrease in the meshes of the lace-like pattern of the iris which tells at once that the condition is a natural one. The pupils will respond to light both singly and associately, showing that the cerebral nuclei, as well as the pupillary light reflex arc and the cilio-spinal center with the cervical sympathetic from the same, are normally active. The contraction of the pupil is mostly done at the expense of the larger contour of the parabolic curve of the pupil circumference proving that the sphincter is an incomplete or unclosed one, being attenuated at the open extremity where it fades into the iris tissue stroma.

How do we account for upward, inward or outward congenital coloboma? Here we must look for causes other than failure of the ocular cleft to close in embryo. The first thing that attracts one's attention in these cases is that no corresponding dehiscence exists in the ciliary, suspensory ligament, choroid or retina, as is so often seen associated with the classical coloboma due to delayed closure of the ocular cleft. Moreover, the eye is fully developed and the function is apt to be quite up to the normal standard. We must then accept Collins' and Mayou's theory (*Pathology and Bacteriology of the Eye*—Pyle) that in these atypically placed colobomata of the iris the fault is due to retardation or hindrance on the part of that portion of the edge of the primary optic cup in its effort to force its way under the anterior vascular sheath of the lens which corresponds to the location of the coloboma. As mentioned previously *(vide Aniridia)* there may exist abnormal adhesion between the lens and its anterior vascular membrane at one or more points which will arrest the iris-forming cells growing from the edge of the optic cup behind that point, thus causing a gap beyond the point of such attachment. Indeed cases have been met with in which there are two or more colobomata in the same eye, a thing impossible to explain by any other hypothesis than that of abnormal adhesion between the lens and its anterior investing vascular sheath to hold back the cells growing between to form the iris.

In other cases we find that the pigment layer of the iris was formed to the normal limitation, but that the substantia propria had failed to develop in a path running from the pupil margin to the periphery, thus producing a *pseudo-coloboma.*

The pigment layer is the product of the epiblastic tissue found at the edge of the secondary optic vesicle, while the iris stroma (bloodvessels, muscles, connective tissues) is the product of adjacent mesoblast growing apace with the epiblastic cells. It is hard to conceive that the one could grow past an adhesion and the other not, so that here we assume that a ciliary bloodvessel-stem impedes the one and not the other. In pseudo-coloboma the pupil by simple inspection seems to be like a key-hole if running to the periphery of the iris, but on focal illumination and examination with a magnifying lens it is found that the actual pupil is round and central, the brown pigment of the posterior surface of the iris being exposed through a gap in the iris stroma. Collins and Mayou state,—"This defective deposition of stroma is most likely due to an absence of some of the anterior ciliary bloodvessels."

Coloboma of the iris in each eye, occurring in five generations. Simeon Snell reported before the Ophthalmological Society of the United Kingdom (*Ophth. Record,* Vol. XVII, No. 4) this condition in members of the same family through five generations. There were forty-one persons accounted for in these generations; twelve of whom were affected, five males, and seven females. In the great, great, grand-children the defect was complete aniridia.

Color changes of iris in pupil contraction. Gstettner (Pfleuger's *Arch. f. d. ges. Phys.,* CV, p. 355) finds that the iris becomes lighter in color when the pupil contracts and that the change of color is due to a yellowish tinge, brown irides becoming tan-like, blue irides becoming gray-like, etc. He explains these changes of color by the theory that there is a double refraction of light by the fibers of the iris which are on the stretch.

The change of color by other observers has been ascribed to the widening of the iris crypts and obliteration of its folds, thus separating the pigment cells and exposing the interstitial tissue which is non-pigmented. Still others maintain the change of color is a pure interference phenomenon.

Comparative reaction. Abelsdorf (*Archiv. f. Augenheilk.*, XVIII, No. 1, p. 64), experimenting on day birds as regards the pupillary reaction to differently colored lights, noticed a diminished reaction to red and green in comparison with man; but in night birds (owls) the reaction to these colors was excessive. In dogs' eyes the pupils react to colored lights the same as in human beings, but in cats' eyes the pupils reacted similarly to those of owls, i. e., there was increased reaction to blue light.

Concentric contraction of the pupil. Hummelseim (*Arch. of Ophth.*, November, 1910, Vol. XXXIX, p. 579) experimented to determine whether the contraction in miosis takes place concentrically or whether the center of the pupil alters its position when the sphincter contracts. The apparatus designed by Hess was used in 130 eyes. The result showed in all cases that the pupil contracts and dilates concentrically. This observation differs from those of Grossman (*Brit. Med. Jour.*, September, 1903, p. 11) who concluded that during contraction the pupil moves inwards and upwards, inwards and downwards, or simply inwards.

Most observers are agreed that the pupil contracts concentrically and that the geometric center of the dilated pupil is the same exact point as the center of the same pupil when contracted.

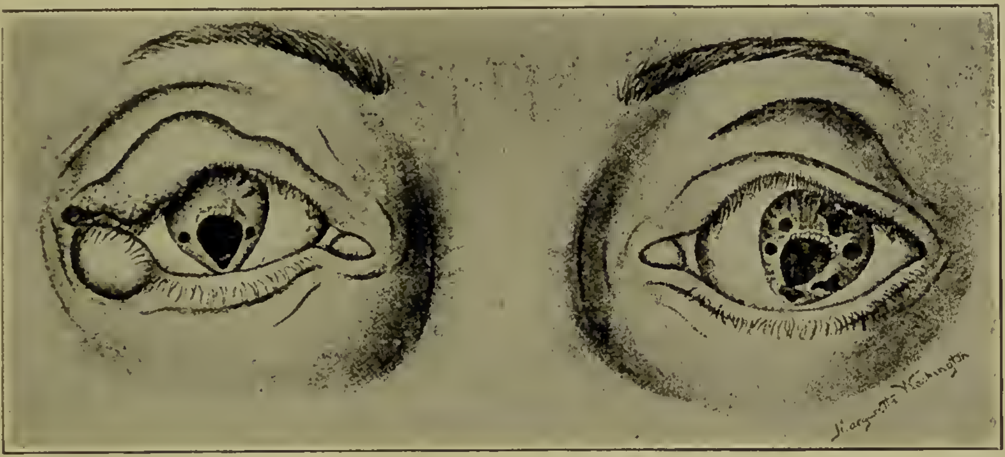
Concussio-oculi. If the pupil shows displacement, ovality and slight dilation, there is in case of direct traumatism to the eyeball a strong likelihood of the lens being partly dislocated. The pupil is not unusually paralyzed from direct injury. If paralysis comes on gradually after several hours it often remains permanently dilated. (See also *Dislocation of the lens* in this section.)

Congenital anomalies. (a) Acoria. (b) Persistent pupillary membrane. (c) Aniridia. (d) Coloboma of iris. (e) Polycoria. (f) Corectopia. (g) Microcoria. (h) Discoria. (i) Iridodonesis (congenital).

For description and discussion of each of these anomalies see elsewhere in this section alphabetically arranged. (See, also, *Coloboma familias,* this section.)

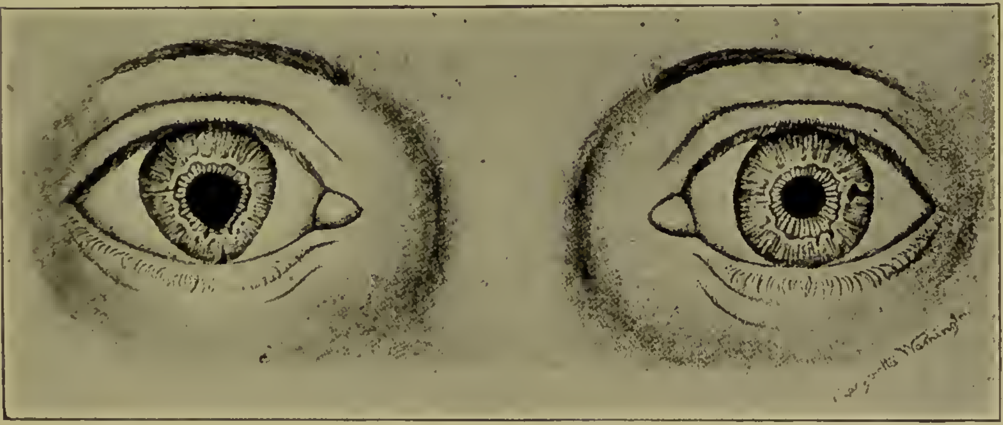
Congenitally dilated and immobile pupils. Emerson (Knapp's

Archiv., January, 1911, Vol. XL, No. 1, p. 103) reported the case of a child of twelve who presented dilated and immobile pupils with no other evidence of ocular disease since birth. The pupils did not respond to any test but the vision and accommodation were normal. In the discussion, Wootton suggested that there was probably congenital absence of the cerebral nuclei controlling the pupils.



Right Eye. Left Eye.

Case I.—Mother.



Right Eye. Left Eye.

Case II.—Daughter.

Posey's Cases of Congenital Pupillary Anomalies in Mother and Daughter. (*Annals of Ophth.*, Jan., 1903.)

Contour, Irregular. Irregular contour of the pupil margin may be normal, as from congenital (embryologic) causes. Piltz noticed in normal infants that at birth the pupil contour is not always regular but soon becomes so. He thinks this irregularity is due to tardy function of parts of the iris. Flattening of the pupil on one side may occur. If the upper-outer half is affected in this manner there may be a lesion of the outer branch of the long ciliary nerves; if the lower-inner half presents this appearance, the lesion may be in the inner branch of the long ciliary nerves.

Posterior synechia cause contour irregularities from mechanical causes as well as from the organized adventitious tissue that tends to flatten the pupil at the site of the adhesion.

Irregularities of contour may be (a) shifting or (b) fixed. Shifting irregularities of contour from one side of the pupil margin to another have been observed by Piltz in progressive paralysis and catatonia. Fixed irregularities are quite frequently seen in tabes and paresis and constitute an early sign. The "battered" contour of the pupils seen in these diseases, and other degenerative diseases of their class, is due to paralysis of terminal nerve strands supplying one or more segments of the iris, causing in time a sectional atrophy of the iris musculature. (See also *Deformed pupils* in this section.)

Consensual reaction, Measurements of the pupils in. Abelsdorf and Piper (*Archiv. f. Augenh.*, LI, 4, p. 366) photographed the pupils when one was in shadow and the other exposed to bright light and found they were unequal in size. The pupil exposed to light was invariably smaller than the one in shadow. This test proves conclusively that the common teaching that the pupils are equal by this test is erroneous. Moreover, that the illumination should be equal in examination of the pupils for pathologic inequality.

Contraction, Primary and secondary. The normal pupil strongly contracts when the eye is suddenly exposed to light, then there follows a slight relaxation in the same light and another contraction which is not quite so marked as the first and after that the pupil usually remains contracted. In some cases the pupil will perform a series of slow contractions and rapid relaxations (oscillations) while in morbid states (neurasthenia, etc.) the rebounding of the pupil is striking and characteristic (hysteria, insanity, etc.) when it is known as "hippus." The primary action is often so quick as to escape detection; the secondary reaction is usually the first seen.

Contraction from congestion. The iris is a vascular membrane. If the arteries and capillaries which it contains are distended from any cause the pupil contracts. This contraction is in proportion to the amount of distension and therefore is an index of itself of the severity of the reaction which causes the vascular congestion. In cases of iritis the iris is swollen. It therefore occupies more room than before. Since it cannot spread at the root which is fixed it needs must spread at the margin of the pupil which is motile. Thus the pupil is made to contract in congested states of the iris.

Contraction to light and convergence compared. Kanngieser (*Arch. f. Augenh.*, LXIII, No. 1, 1909) tested to determine the comparative contraction of the pupil by light and convergence. For convergence the eyes were fixed on a point six inches away and for the light reflex test a gas light was placed twelve inches from the eyes and allowed to illuminate the macular region. The width of the pupil in each test was taken with Haab's pupillometer. One hundred healthy persons of various ages were thus examined. The following table shows the difference in the average diameter of the pupil in millimeters in five successive decades of life beginning with the second.

Age.	Light.	Convergence.	Difference.
10 to 19	3.5	3.9	+0.4
20 to 29	3.5	3.7	+0.2
30 to 39	3.7	3.6	—0.1
40 to 49	3.3	3.1	—0.2
50 to 59	3.1	2.9	—0.2

From this table we note that from the tenth to the thirtieth years contraction from light is greater than from convergence, while from the thirtieth to the sixtieth years the pupils contract more to convergence than to the light. It was observed in this series that sex and coloration of the iris have no influence on the size of the pupil by these tests. (See *Width of pupil,* this section.)

The pupil has been made to contract when the internal rectus was stimulated to produce convergence by means of the electric current, when no central effort was employed, and even when the eyeballs have been grasped by forceps and made to converge without muscular contraction, pupillary contraction was noted.

Bernheimer (*Neurolog. Centralb.,* XV. 11, 1899) holds that these experiments go to prove that there can be no cerebral center for convergence contraction. (See *Ciliary ganglion as a peripheral center* in this section, also *Miosis.*)

Corectopia. The normal position of the pupil is not always in the geometric center of the iris, but is often slightly toward the nasal side and a little below the horizontal meridian. In many cases this normal eccentric position of the pupil is apparent at a glance but such is not called "corectopia" unless the pupil placement is conspicuously eccentric. The condition is associated very often with a downwards and inwards subluxation of the lens, but the ectopia lentis may be so slight as to baffle one's attempt to prove its existence. The inference is that the ciliary processes, and likewise the three sets of fibers of the suspensory ligament in that quarter of the zonule toward which the pupil is misplaced, are either not formed at all or are rudimentary and imperfect which causes lens-tilting in the act of accommodation, so that we may suspect cyclophoria in cases of corectopia. These pupils do not dilate and contract to the normal extent, either when tested with alternate light exposure or with mydriatic and myotic drugs, leading us to the opinion that the musculature is deficient. The condition is non-pathological and constitutes a congenital curiosity, but it has its practical side in that there is usually associated a certain amount of amblyopia partly due, it would seem, to the partial microphthalmia present and partly to the frustrated effort of normal accommodation. Lens-astigmatism is usually demonstrable. If the pupil can be sufficiently dilated with a mydriatic the lens-margin may be seen to be notched on the side corresponding to the narrowest side of the iris, proving conclusively that suspensory fibers are wanting in this locality and that, indeed, subluxio-lentis is present; but often this finding is not demonstrable.

Corectopia is a developmental fault and not the result of intrauterine iritis as has been thought. Just why this anatomical defect forms is unknown, but the inference is that there was ''defective budding out of the ciliary processes as well as of the iris, so that the adhesions between them and the lens capsule which become the suspensory ligament failed to form'' (Collins and Mayou *Pathology and Bacteriology of the Eye*—Pyle.)

Corectopia like other congenital anomalies has been often found in cases where the parents are blood relatives, e. g., first-cousins. In some cases there is no ascribable cause. The condition, which is usually present in both eyes, is conspicuous but there is no remedy to offer other than the proper attention to the refraction anomaly usually present. Traumatic corectopia is another condition which is mentioned elsewhere in this section.

Here owing to the flaccidity of the iris tissue, aided by the gush of aqueous, a perforating wound of the cornea permits the iris to be forced into it, causing the pupil to be drawn in the direction of the injury. Usually a pear-shaped contour results.

Corescope. (The terms ''corescope'' and ''pupillometer'' are synonymous.) De Surel (*Rev. gen. d'ophtal., XXIV,* p. 289), describes his corescope which consists of a frame in which two black threads are so arranged that they form an acute angle like the letter V. The frame is passed in front of the eye until the two threads correspond to the margins of the pupil. The diameter is then read from a scale on the frame. (For a description of other instruments used in measuring the pupil, see *Pupillometer.*)

Cortical blindness, Graefe's reaction in. It has long been known (Graefe) that in complete bilateral cortical blindness the reaction of the pupils to light, despite the complete absence of all perception of light, is extremely striking. Knies reports the case of a boy with bilateral cortical blindness whose pupils reacted perfectly to light and moreover who would direct his eyes toward a source of light held to one side and would also close his eyes as if to protect them from the strong light held directly in front of them and this, too, in spite of the fact that he did not possess the faintest perception of light.

Cramp (pupil) as a cause of pain. Fridenberg, of New York (*Ophthal. Rec.,* August, 1905, Vol. XIV, No. 8, p. 357), analyzes and compares the various theories as to the cause of pain in the eyes when suddenly dazzled with light, and also the pain associated with the presence of a foreign body in the eye, abrasion of the cornea, iritis, cyclitis, etc. The retinal fibers are, in themselves, incapable of transmitting painful sensations for they are specialized nerve fibers concerned solely in transmitting sensations of light. But the stimulation of the pupillomotor fibers in the retina by light causes reflex contraction of the pupil and this reaction to glare may be so sharp and sudden that cramp of the sphincter pupillæ results. Pain is always a symptom of cramp in any muscle of the body and the sphincter iridis is no exception. The pain incited by the entrance of a foreign body in the eye, or an abrasion of the cornea, etc., is due to direct insult to sensory nerve endings in the cornea.

Fridenberg says,—"The matter may be understood if we admit that pain is not strictly connected with special *efferent* nerves, but results from excessive excitation of any *centripetal* nerves." The localization of this reflex pain is very inexact. Von Frey states the optic nerve is incapable of painful sensation and he believes the pain from dazzling is due to violent contraction of the sensitive iris. Nagel (*Klin. m. f. Augenh.,* XXXIX, p. 879), tested this view by dilating the pupil with homatropin and subjecting the patient to glare to see if pain resulted. He found that in spite of the dilated pupil, which admitted much more light, there was no pain to this test. He therefore agrees with von Frey that photophobia and pain are due to tonic spasm of the sphincter pupillæ. Axenfeld accepts this view to explain the beneficial action of atropin in cutting short the photophobia of phlyctenular keratitis. But Bjerrum (*Hospitalstid,* May 6, 1903), disagrees with these observers and states that the contraction of the pupil has little if anything to do with causing pain in these cases. He thinks the pain is of a reflex nature proceeding from the optic tracts to the sensitive tracts of the eye. The latter are hyperesthetic and the ordinarily non-painful stimuli set up in these patients a painful response on account of their exaggerated sensibility. This opinion he holds supported or proven by the fact that the pain is more promptly relieved in abrasion of the cornea and phlyctenular keratitis by the use of cocain drops in the eye than by atropin on account of the anesthetic influence of the former on the sensory nerve-endings of the cornea. Bjerrum therefore holds to the theory of Handfield Jones that the photophobia of phlyctenular keratitis is the expression of a primary hyperesthesia of the retina induced by defective nutrition and a weakened constitution, and is not due to cramp of the iris and contracted pupil. He states further that eserin solution will contract the pupil and stimulate a tonic spasm of the sphincter pupillæ more completely than does a bright light, and causes no pain. But Fridenberg points out that this contraction of the pupil takes place gradually and that it is therefore different from the spasm-contraction so quickly induced by glare. Bjerrum says that the pain in photophobia associated with phlyctenular keratitis is always in the affected eye although the pupil of the unaffected contracts as sharply and as much as that of the affected. Fridenberg answers this by stating that the pain in this, as in abrasion of the cornea, etc., is due to direct irritation of the sensory nerve endings in the cornea and should not be confused with the reflex pain due to iris cramp. This observation is further strengthened by Bjerrum's own argument as to the anodyne action of cocain as compared with atropin, for the nerve-endings are anesthetized with cocain. Bjerrum's view that the irritation is in the perceptive mechanism and is referred from the optic nerve to the sensitive tracts in the eye, and that the spasm of the eyelids is a defensive effort of nature to protect the retina from the light, is rebutted by the fact that in abrasions of the cornea, foreign body in the eye, phlyctenular keratitis, etc., the pain is present when the eyelids open and shut in the dark.

Roemer opposes the view of Nagel and Axenfeld that cramp of the pupil causes the pain and photophobia, on the grounds that no such analogy occurs in any other muscle of the body, that pain does not accompany sudden and violent contraction of any muscle, but Fridenberg points out that the analogy does exist in the case of cramp which is very painful and may occur in any muscle and states that Roemer neglects the factor of adaptation that plays the most important rôle in physiological muscular action. Roemer agrees with Bjerrum that eserin contraction of the pupil is not painful and therefore rules out the argument that pain is due to contraction of the pupil, but Fridenberg reiterates that it is not the contraction of the pupil alone that causes the pain but the *sudden, startling* and cramp-like contraction which incites the pain, photophobia and blepharospasm. Eserin requires from five to fifteen minutes to induce miosis and the muscle becomes adapted in this time. Roemer argues that he instilled eserin in the eye and found that bright light caused much less dazzling and pain, but Fridenberg answers this by stating that in this instance the fibers of the sphincter were already adapted to the contraction impulse and so were prepared, as it were, for the added reflex contraction to light. Fridenberg draws a sharp contrast between the pain associated with tonic spasm of the sphincter iridis induced by glare and the pain associated with inflamed or irritated nerve-endings of the cornea with which we also find contracted pupil as a common symptom. The former is best illustrated by the sharp discomfort that is felt in normal eyes when exposed to sudden glare after being adapted to comparative darkness. "The sudden spasm of the pupillary sphincter causes an aching, colicky pain which by analogy with similar conditions in other muscular structures is due to sudden stretching of the iris tissues and which is relieved in a second or two as the pupil contracts." This dazzling, according to Wilbrand and Saenger, produces a narrowing of the palpebral fissure to produce a stenopaic slit or by the expression known as the "sun face" so commonly exhibited by people who have lived in-doors when they go out in the sunlight.

The entrance of a jagged cinder in the eye will instantly occasion the most exquisite photophobia. The lids close spasmodically on the cinder and the tears stream from the eye. The pain is excruciating. Fridenberg asks that, in this instance, are we to assume that in less than a second the sensitive tracts have become intolerant to light? The pain and photophobia in this case are not from spasm of the pupil but from nature's effort to immobilize the eye and protect the organ from further injury. Fridenberg therefore concludes there are two classes of photophobia and that they differ radically as to cause and mechanism, although both may exhibit the same external and superficial manifestations. They may be indicated as,—*First,*—Specific, idiopathic, primary, retinal or true photophobia due to iris cramp causing actual pain. *Second,*—Secondary, symptomatic, superficial, corneal or pseudo-photophobia due to inflammation or irritation of the sensory nerve-endings in the cornea, and independent of any cramp of the pupil or reflex irritation from the retina.

Cramp cured by iridectomy. Bronner read a paper before the Ophthalmological Society of the United Kingdom in December, 1911 (see Knapp's *Archives*, 1912, Vol. XLI, No. 2), in which he noted painful spasms of the sphincter pupillæ in ulcer of the cornea. Iridectomy promptly gave relief by putting the sphincter muscle at rest.

He was able to prove the cramp of the pupil from the fact that it refused to dilate with atropin. He also proved that the iris was not inflamed, for after the pupil was cut it dilated readily with atropin. He assumes that there is inflammation of the sensory nerves of the cornea in case of abrasion or ulcer which causes a reflex spasm of the sphincter pupillæ; and that this in turn prevents the ulcer from healing on account of the congestion.

Lawford, in discussing the condition, recalled the instance of a man who had been to see several ophthalmic surgeons with an unhealed ulcer that went on to healing as soon as the sphincter was cut by an iridectomy. Bronner had previously reported (*Ophthal. Soc., U. K.,* Dec. 10, 1908), his results from performing iridectomy during the acute stage of plastic iritis where the pupil refused to dilate with atropin. He had performed this operation in six such cases in direct contravention to the teachings laid down in most text-books, that iridectomy should never be performed during an inflammatory attack. His results were so happy that he now lays down the dictum that iridectomy should be performed in all cases of iritis in which, after three or four days' use of atropin, etc., the pupils refuse to dilate. There were in his cases moderate decrease of inflammation and pain, liberation of adhesions, prevention of occlusio-pupillæ and secondary glaucoma, but he admonishes strongly that this operation must *not* be done in cases of serous iritis or iritis in sympathetic ophthalmia.

Cranial deformity, The pupil in optic atrophy associated with. Friedenwald (*Arch. of Ophth.*, July, 1901, Vol. XXX, No. 4), reports on 19 cases of variously malformed skulls, principally steeple-shaped. The only pupil manifestation mentioned was widely dilated pupils. It is well known that in cases of megalocrania, atrophy of the optic nerves and consequent blindness are commonly observed and in such cases we usually find widely dilated and fixed pupils. This is explained by the total blindness due to atrophy rather than from involvement of the pupillary centers.

Cryptophthalmia, The pupil in. Everhardt (*Ophth. Record,* Vol. XX, No. 1), reports the case of a child born with no palpebral fissures, the skin of the brow being continuous over the base of the orbits and no lashes present. There were prominences indicating the presence of eyeballs in the orbits. Sections were made along the prominences where the fissures were indicated. The eyeballs exposed by this operation showed some enlargement of the left, the right being normal in size, and both presented a uniform dark-blue color, like a ripe grape. There was no trace of pupil or red reflex. The incisions grew together again. The parents were first cousins.

Other cases of this nature have been reported by Hoover in the *Journal of the A. M. A.*, Vol. LV, No. 5.

Cyclic mydriasis and miosis in congenital third nerve palsy. Franke (*Klin. Monats. f. Augenh.*, Nov., 1909), reported two cases of this rare behavior of the pupil which was first described by Axenfeld and Schürenberg. It consists in a very peculiar mydriasis alternating with miosis in cases of congenital or early-acquired paralysis of the third nerve. The pupil would dilate to 5 and 6 mm. in diameter, remaining in this condition for from 5 to 20 seconds, and then would rather rapidly contract to 1.5 and 2 mm., persisting in this contracted state for from 10 to 20 seconds and then slowly dilating to its former state, repeating the performance over and over again. The pupil under observation did not respond to light or accommodation. The ciliary muscle acted in the same manner and along with the pupil behavior, which observation was also made in eight cases reported in the literature on the subject. In one case reported by Axenfeld and Schürenberg, the anomalous behavior of contraction and expansion of the pupil in the cyclic manner described was observed even during slumber. The cases were all girls, with one exception. The boy was the only case in which the condition was bilateral.

Coats (*Arch. of Ophth.*, July, 1914, Vol. XLIII, No. 4), reports the interesting pupillary behavior of a girl, aged 10, which he states was noted from birth. There was rapid contraction and gradual dilatation of the pupil which occurred in a cycle. The movements were not strictly rhythmical but were fairly so and they continued to work regardless of the effect of light and also regardless of the direction in which the patient turned her eyes.

During the phase of contraction the pupil was immobile to light, but during the phase of dilatation it responded to light singly and consensually. There have been nineteen cases of this affection recorded; the condition is invariably associated with partial paralysis of the third nerve.

It was Salus' opinion that nature's effort to repair a lesion of the third nerve caused some of the axis cylinders to sprout from the central end and make a "false junction" connecting a live nerve center with a group of muscles not belonging to it. If for instance all the fibers which should go into the internal rectus were diverted to the sphincter pupillæ, then an effort at adduction would result only in contraction of the pupils. (See *Changing pupils* in this section, also *Jumping pupil.*)

Cyclops, The pupil in. Dougal, Daniel and Milens (*Brit. Med. Jour.*, July 4, 1914), report the case of a cyclops, still-born, which had a single orbit containing two eyeballs fused together in the middle line. On the anterior surface of each half of the globe was a complete cornea through each of which could be seen an iris enclosing a circular pupil.

Bogoslawsky described the case of a monster with only one eye in which there were two pupils. Another case (*Arch. d'ophthalm.*, Vol. III, p. 469), of a human fetus six months old is reported as having only one orbit and one eye which was very small. There was no cornea and no iris but there were two lenses.

"Deafness," reflex, of Heddaeus, or "Amaurotic rigidity" of Bach. This is the ordinary non-response of both pupils when one eye, blind from a lesion in front of the optic foramen (e. g., atrophy of one optic nerve) is illuminated, while if the fellow eye that is functionating normally is illuminated, both pupils contract equally. It is the "consensual reaction test." Cases have been reported, however, in which one eye is blind and yet in spite of this fact the pupil of this eye responds to direct light (Jessop,—*Lancet,* July 11, 1891).

Reichardt (*Deut. Zeit. f. Nerv.,* XXV, 1904, 408), had such a case in which he was fortunate in securing a microscopic examination of the optic nerve, finding the fine (visual) fibers entirely atrophied and the coarse (pupillomotor) fibers mostly normal. (For further discussion of amaurotic pupillary rigidity, see *Pathology of the pupil* from Bach elsewhere in this article.)

Death. Atropin and eserin in the cadaveric eye. Groenouw (Ophthal. Socy. Heidelburg, 1910), states at the moment of death the pupil dilates and then it gradually contracts during the following day or two. This contraction is due to *rigor mortis.* In order to control the experiments that he made atropin solution was dropped in one eye and eserin solution in the other of the cadaver. The difference in the size of the pupils was very distinct in an hour's time. The eserinized pupil was much smaller than the atropinized. The difference measuring 2 to 3 mm. in the former and 5.5 to 8.5 mm. in the latter. The effect lasted from seven to nine hours, after which it was noted that the contracted pupil had dilated and the dilated pupil had contracted, but there was a difference still noted after twenty-four hours.

The effect of these drugs could be produced if instilled in the eyes before three or four hours after death, but later than that no effect could be produced. These observations become of value in legal medicine in order to determine the time that had elapsed since death. Brown-Sequard obtained contraction of the pupil by light in an iris that was excised, and deRupter dilated the pupil with atropin in an eye that had been enucleated. (See *Anatomy of atropinized eyes* herein.)

Death, Impending. Riley (*New York Med. Press Cir.*, July 5, 1916), states that in a very sick patient whose pupillary reflexes were previously normal and in whom there develops no pupillary reaction to light, death is at hand. He excepts cases of previous impairment of the pupil such as spinal miosis of the aged, syphilis or its sequelæ, brain diseases, optic atrophy, fainting and hemorrhage. In most diseases just before death the pupil widely dilates. The "death stare" or "fixed eye" is probably due to the dilated non-reacting pupil and death is near at hand although the patient may count fingers and respond to questions.

Decapitation. Axenfeld (*Arch. of Ophth.*, March, 1904, Vol. XXXIII, No. 2, p. 186), stated that he had examined the pupillary reflexes of four decapitated criminals immediately after death. In one of them the pupils reacted to the light for thirty seconds after decapitation. In the others there was no reaction. He therefore doubts the statements found in literature that after decapitation the pupils react for from several minutes up to a half-hour.

Bach, experimenting with decapitated animals, observed the light reflex of the pupil for only a few seconds after decapitation.

Deformed pupil, Diagnostic value of. In an editorial in *Ophthalmic Record,* Jan., 1905, we are reminded that we may often overlook a slight deformity of the pupil or fail to appreciate its significance when noticed. The dilator pupillæ is supplied by two long ciliary nerves from the sympathetic. One supplies the upper and outer, the other the lower and inner, half of the iris. Paralysis of either of these will cause a sectional miosis on that side, or a distinct flattening of the circular contour of the pupil on the corresponding side. The effect of a mydriatic on such a pupil is to dilate the unparalyzed half and leave the paralyzed half only slightly dilated. Miotics on the other hand obliterate the flattened contour.

The sphincter pupillæ is supplied by a number of small nerve branches from the ciliary ganglion and is regarded to be under control of a component of the third nerve. Paralysis of one or more of these nerve strands would produce a sectional partial mydriasis of the corresponding part of the pupil. In this case we note an arching of the circular contour corresponding to the paralyzed section of the pupil. Mydriatics will obliterate the defect while myotics will exaggerate the same, but both will influence the affected segment of the sphincter even though somewhat feebly. The recognition of these deformities is important for they rarely exist in health and are nearly always the advance or premonitory symptom of grave disease of the central nervous system, such as tabes, general paresis or multiple sclerosis. Joffroy, Bumke and others state deformity of the pupil is invariably present in cases exhibiting the Argyll-Robertson phenomenon. It has been ascribed to atrophy of a segment of the iris. (See *Contour,* also *Sectional dilatation* in this section.)

Degeneration stigmata. Albrand (*Archiv. f. Psych. u. Nerv.,* XXXIV, p. 121), found the pupils abnormal in size and reaction in early life in seven per cent. of subjects affected with degeneration stigmata.

Dementia præcox, The pupil in. Tyson and Clark (*Arch. of Ophthal.,* March, 1908, Vol. XXXVII, No. 2, p. 239), state that the pupils in all their cases of dementia præcox presented uniform symptoms. *They were all dilated.* There was no sensory reflex, no psychic reflex and no Piltz reflex. They state since no other psychosis presents these conditions the appearance of the pupils should be found useful in the differential diagnosis. The same observers (Knapp's *Archiv. Ophth.,* Vol. XLI, No. 3, May, 1912, p. 227), examined the pupils in 85 cases of dementia præcox, comparing them with the pupils of normal persons, and found that in the 85 cases they studied the pupils were dilated on an average of 1.1 mm. more than the normal. The widths varied by measurement between 3.5 mm. and 7 mm. Moreover, the reaction was almost invariably sluggish to light and the sensory reaction was usually absent. The Galassi-Gifford reflex was present in only two cases. The somewhat dilated and sluggish pupils appeared to be due to loss of function through defective nerve energy, aided by mental obtundity and diminished apperception.

The condition of the pupils, together with diminished corneal sensitiveness, concentric contraction of the visual fields and the dilated, dark, retinal veins and contracted arteries with changes of the disk, constituted the almost constant ocular signs of the disease in this group of cases.

Bumke (*Med. Klink.,* 1907, p. 1221), states that in dementia præcox the dilatation of the pupil from psychic and sensory irritation is absent in about 6 per cent. of the cases. In katatonic stupor the pupils are sometimes transiently elliptic and react slowly or not at all. In hysteria similar disturbances are met with although here the pupils are usually dilated ad maximum or contracted markedly. If the latter, there is associated spasm of convergence. Later on Bumke studied thirty-three cases of dementia præcox, and found the pupils larger than normal in all. The pupils measured from 5.5 to 9 mm. in diameter; moreover, they were equal in size in nearly all his cases.

He also noticed in this series, absence of psychic reflex, reduction of pupil motility, and loss of dilatation to sensory stimuli. Mignot calls attention to the variable behavior of the pupils from day to day and regards this to be peculiarly characteristic of dementia præcox. Moreover in this disease the circular contour is often altered, producing the "deformed" pupils—this was noted in 52.6 per cent. of Mignot's cases.

Dental origin of mydriasis. Verrey (*Ann. de'oculistique. CXLVII,* p. 189), reports the case of a woman of thirty-four, who had mydriasis of one eye caused from the late cutting of a wisdom tooth. The tooth was extracted and the day following the mydriasis disappeared. He argues that the dilatation was probably produced by irritation of the cervical sympathetic nerve excited by inflammatory irritation of its trunk.

Detachment of retina. Bach states that separation of the retina gives a slightly enlarged pupil when no complication is present. In a few cases it could be determined that the reaction was less prompt on throwing the light on the separated area. In some cases where the vision was very poor the light reaction was prompt.

Laquer (*Archiv. f. Augenh.,* LIX, p. 527), found the pupillary reaction was uniformly the same whether the detached or the normal part of the retina was illuminated.

Diagnostic value of the pupil. At a joint session of the Chicago Ophth. and Neurol. Societies (*Ophth. Record,* May, 1910, Vol. XIX, No. 5), Gradle the elder, discussing the value of eye symptoms in the diagnosis of nervous diseases, mentioned one-sided pupillary contraction with immobility in paralysis of one cervical sympathetic; one-sided pupillary dilatation and immobility without other involvement of the third nerve in cerebral syphilis; pupillary inequality in various psychoses; bilateral pupillary rigidity usually with miosis in general paresis or tabes and sudden loss of accommodation with normal pupil in post-diphtheritic paralysis.

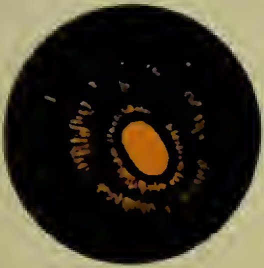
E. Jackson (*Am. Jour. Med. Sciences,* Oct., 1908), quotes Swansey as saying "The condition of the pupils whether normal, contracted or dilated, is of very slight significance or value in the diagnosis of either the location or kind of any intracranial lesion." Nevertheless, as Jackson states, "The pupil is enormously suggestive to anyone who is on the lookout for clues." The unilaterally dilated pupil may suggest cerebral disease, phthisis pulmonalis (see elsewhere in this section) paresis, cerebral syphilis and many other diseases and abnormal states. Moreover, in the case of brain lesion the side of the lesion may occasionally be determined from the dilated pupil on the same side. The pupil may be dilated on one side the result of aortic aneurism, as explained elsewhere in this section, but sometimes, as in the case of phthisis, the dilatation passes over into a miosis when the disease advances to a later stage. Irritative conditions of the sympathetic cause dilatation, and destructive lesions miosis. The one-sided dilatation of the pupil is always strongly suggestive of syphilis and the reflex iridoplegia to light with miosis (Argyll-Robertson pupil) is by many not only regarded as a symptom of tabes but also of syphilis.

Jackson states that in his locality (Denver, 5,280 ft.) the high altitude frequently causes ophthalmoplegia interna which is more in evidence in one eye than in the other and that such cases are always benefited by a sojourn in a low altitude.

If the pupil reacts normally it does not necessarily mean that the person possesses good health, but if the pupil does not react normally there is always some abnormality present either in the eye itself, or the nervous or vascular system.

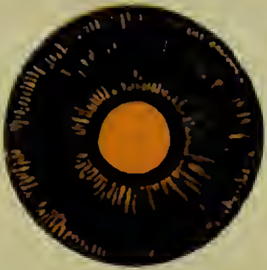
Ballantyne (*Ophthalmoscope*, July and August, 1909), reviewed the literature on the anatomy, physiology and pathology of the pupil from sixty-one sources (references fully cited) including the work of the world's most authoritative and advanced workers, thinkers and writers on the subject within the decade just preceding and concludes that, "It cannot be said that a great deal has been added to our precise knowledge of the significance of the pupil in general medical diagnosis;" and furthermore, "Probably of no disease can it be said that a pupil symptom is pathognomonic; it is much more often only a link in the chain of evidence, for, although in many cases the state of the pupils is fairly constant for the disease in question, it also belongs to other conditions." It seems that in spite of the excellent work that has been done there is a lack of precision in methods of examination as well as a distinct lack of knowledge in the interpretation of pupillary behavior and misbehavior, the extenuation being somewhat because of the fact that much is lacking in the way of exact proof and full knowledge of the cerebral and cord centers and tracts and the interlacing, communicating, crossing and recrossing of the fibers concerned in the complex act of pupil contraction, expansion and inaction to various stimuli in health and disease. The subject will be better understood when the anatomical, histological and physiological data are all traced and fully understood. Nevertheless, enough is known and proven beyond doubt to render the subject of the various reactions of the pupil worth one's while to study, as Ballantyne says, "if it were for no other reason than to guard against errers in interpretation."

1



Medium Pigmented-Brown Iris, Eserin Myosis

2



Lightly Pigmented Blue Iris

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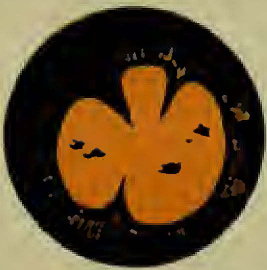
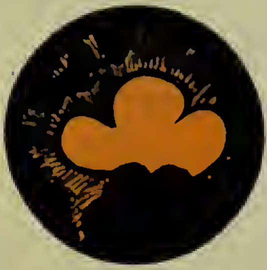


Iritic Synechiae, Pigment Deposits on Capsule and Dehiscences

4



Syphilitic Iritis and Gummata

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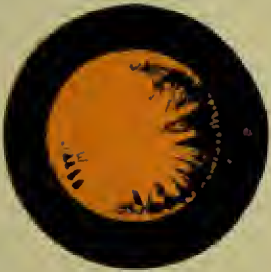

Partial Cortical Cataract

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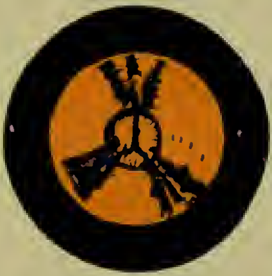

Lamellar Cataract

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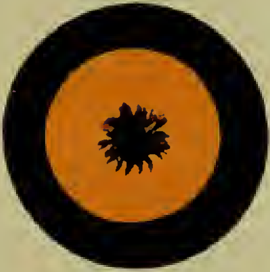

Anterior Capsular Cataract

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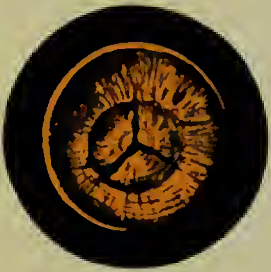
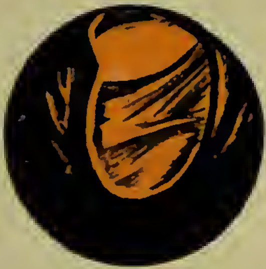


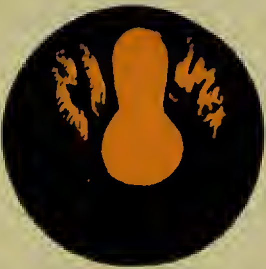
Total Opacity of Lens showing Nucleus and Sectors

9



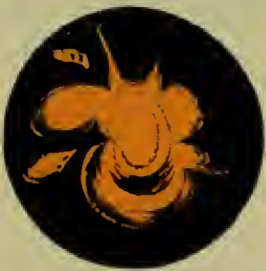
Cataract Extraction with Iridectomy, Impaction of Iris, Capsular Opacity and Dehiscences

10



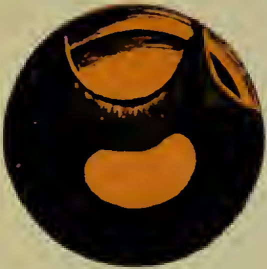
Cataract Expression with good Iridectomy, Pigment Dehiscences

11



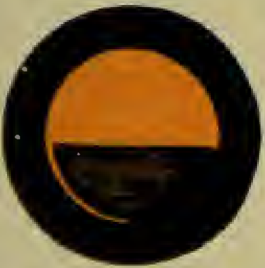
Occlusion of Pupil with Great Pigment Absorption and Thinning of Iris

12



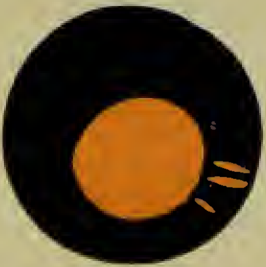
Double Iriodialysis, Rim of the Lens shows plainly

13



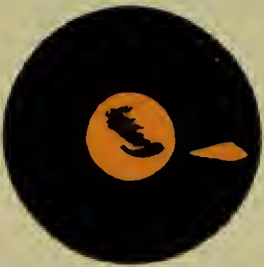
Shadow of Intraocular Tumor

14



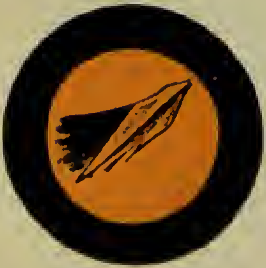
Radial Tears of Iris, Traumatic Mydriasis

15



Steel Chip in Lens Wound in Iris

16



Glass Chip in the Vitreous

Pupil in Diaphanoscopy of the Eye.—Würdemann, *Ophthalmology*, July, 1908.

Bumke (*Muench. Med. Wochens.*, 1907, Vol. LIV, p. 2315), concludes from clinical observations that in nervous exhaustion, physical fatigue, extreme hunger and profound anemia, the pupil is often widened. He observed insane patients who had refused all nourishment and found their pupils were dilated ad maximum on entering the institution, but which, after a few days feeding, returned to their normal size.

He also observed among the attendants of insane patients that the pupils in the morning were always widened after being up all night with the patients, while those attendants who had had a good night's rest presented normal pupils. He considers this (widening of the pupil in exhausted states, etc.,) to be due to increased irritability of the cortex rather than to exhaustion of the sphincter; in other words he ascribes it to cortical stimulation of the cervical sympathetic nerve supplying the dilator pupillæ. He mentions the effect of incomplete oxidation of the blood after exhausted states as being a factor inducing dilated pupils.

Bumke (*Wien. Med. Wochen.*, May 16, 1908), speaking on true reflex paralysis of pupillary reaction states that it was believed to be found only in tabes and post-syphilitic paralysis, but he has found reflex rigidity also in dementia præcox, catatonia and hysteria. Trendelenburg and Bach after numerous experiments on many animals concluded that the medulla oblongata has no relation to innervation of the pupils.

Buzzard (Ophth. Sec. British Medical Association, reported in *Ophth. Record,* November, 1910, Vol. XIX, No. 11, p. 613), stated that inequality and dilatation of the pupils in patients suffering from headaches and vomiting, associated with optic neuritis, he had found post-mortem to be due to a small cyst in the third ventricle. He regards the absence of pupillary light reflex a valuable sign in diagnosing a tumor in the third ventricle or structure immediately surrounding it and mentions that it is not infrequently a local evidence of that disease. It is well known that in severe optic papillitis the pupil often reacts to the light quite normally, but if the disease producing the papillitis is located in or about the third ventricle, we will notice dilated and fixed pupil in one or both eyes. (See *Tumors,* in this section.)

Posey (*Will's Hospital Ophth. Soc. Trans.,* January 7, 1913), spoke on the differential diagnosis between tabes and cerebral syphilis as determined by the pupillary manifestations. He remarks that the observation of Groenouw, viz., that the Argyll-Robertson pupil is generally indicative of tabes and unilateral ophthalmoplegia interna of cerebral syphilis, was true. He formulated the rule that inequalities of the pupils and disturbance in their reaction associated with optic neuritis are found in the early stages of cerebro-spinal syphilis, while palsies of the extraocular muscles belong to the later stage.

In brain tumor there is usually increased cerebral pressure and in this condition there is often if not always some distension of the ventricles and consequently interference with the pupillary centers. This explains the presence of dilated pupils in many cases of brain tumors. Internal hydrocephalus may be a symptom common to brain tumor in any locality and is of no localizing value.

The hydrops of the ventricles may be more marked on one side and in that event the pupil on that side usually is the larger. The distension of the ventricles paralyzes the centers of the sphincter by pressure. Then, too, there is often papilledema and blindness which of itself causes dilated pupils. Anisocoria is common in brain tumors. Hippus occasionally is present. Argyll-Robertson pupils are quite rarely found but when present, according to Uhthoff, the lesion exists between the external geniculate body and the sphincter nucleus.

Major (*Brit. Med. Jour.*, April 16, 1892, p. 818), found the right pupil dilated in a case of tumor of *left* optic thalamus pressing on the internal capsule, there was also right hemiplegia and right hemianesthesia, right facial paralysis and right hemianopsia; optic neuritis was not present.

Dilated abnormally. The pupils may be dilated from unnatural causes and may present three different states:. I. Dilated and responsive. II. Dilated and sluggish. III. Dilated and fixed.

I. Dilated and responsive to light, convergence and accommodation. (a) In myopia; some idea of the degree of myopia may often be formed from the degree of dilatation, the age of the patient taken into consideration. (The pupils are not always dilated in myopia, for in many such cases, perhaps 25 per cent., they appear normal.)

(b) In detachment of the retina in many cases.

(c) In glaucoma simplex in the later stages.

(d) In cortical blindness, as from bilateral hemorrhage in the visual areas in the cuneus.

(e) In some cases of chronic retrobulbar neuritis with large central scotoma.

(f) In some cases of enlargement of the blind spot due to optic neuritis or papilledema.

(g) In total blindness of one eye from ophthalmoscopic disease, as monocular optic nerve atrophy, embolism of central artery, etc., when the seeing eye is screened from the light. The consensual and convergence reaction is preserved but direct reaction is lost.

(h) Reflex from intestinal disorders in infants and children through spinal irritation.

(i) In catalepsy, acute mania and subjective mental states.

(j) In rare central tumors of the brain and also in certain cases of effusion in the brain meninges or the ventricles.

II. Dilated and sluggish reaction. (a) In many cases of near blindness, when the cornea and iris appear normal and where perception of light is still retained, as in profound exudative choroiditis and so-called hyalitis, massive retinitis, hemorrhages in the vitreous, thrombosis of the retinal veins, atrophy of the optic nerve nearly total, advanced glaucoma simplex with retained patch of vision in extreme temple field, intraocular neoplasms that have not entirely destroyed the vision, black cataract, etc.

(b) In many cases of paresis in which we also often note inequality of the pupils (anisocoria).

(c) In many cases of cerebral syphilis and basilar meningitis.

(d) In many cases of tubercular meningitis and epidemic cerebrospinal meningitis.

III. Dilated and fixed. (a) In bilateral total blindness due to intraocular or optic tract lesions from any cause.

(b) In paralysis of the third nerve affecting the innervation of the sphincter pupillæ. Here the vision is usually unaffected excepting from loss of accommodation. This affection is usually expressed in one eye although cases of double oculomotor palsy have been reported.

(c) From the effect of certain drugs instilled in the eye. (See *Mydriatics.*)

(d) In certain cases of brain lesions, such as cerebral neoplasm, abscess, cyst, meningitis and internal hydrocephalus with or without increased cerebral pressure and papilledema; also in paralysis of the nuclear center controlling the sphincter pupillæ, or, in fact, interference with the pupillary light reflex arc in any part of its course, afferent and efferent.

(e) Due to pressure, excessive stretching or severance of the optic nerve or optic tract, as from intra-orbital tumor causing excessive exophthalmos, pressure and strangulation of the nerve at the optic foramen from exostosis tumor or swelling of the orbital wall of the posterior ethmoid or sphenoidal sinus, large tumor or cyst of the hypophysis pressing the optic chiasm, transverse stab wounds which sever the optic nerve, chiasm or tract; gun shot wounds or traumatism from direct or penetrating injuries which destroy the optic nerve or tract.

(f) In certain transitory cerebral states, as syncope, epilepsy, or suspension of consciousness from transitory paralysis of the cortex from any cause.

(g) In certain transitory irritative states of the spinal cord, as from convulsions due to teething or intestinal fermentation and causing high fever, especially in infants and adolescents. (See *Mydriasis* in this section.)

Dilated normally. The pupils may be dilated in health from the following: (a) from the withdrawal of light stimulation to the pupillary light reflex arc, as in subdued light or darkness. (b) from stimulation of the sympathetic sensory nerves, as in tickling or pinching the skin of the face and neck. (c) from cortical stimulation in certain mental states, as in deep concentration, sudden apprehension, absorption, emotion, etc., and (d) from individual peculiarity as often noted in adolescence and in certain persons in middle life as a normal idiosyncrasy. The pupils in the above group all are classified as being normal.

Dilatation of the pupil, to produce after the anterior chamber has been drained. It is well known that the pupil will not dilate by means of mydriatics after the aqueous has been drained through an incision, but deObarrio (*Ophth.*, Oct., 1915, Vol. XII, No. 1, p. 66), dilates the pupil by permitting a solution composed of 1/2,000 adrenalin containing two parts of 2 per cent. cocain solution, to flow into the anterior chamber through a cannula attached to a rubber tubing and glass tube with a rubber bulb. Two or three drops of this solution and a wait of five minutes is all that is necessary to cause the pupil to dilate. He recommends this in the simple extraction of cataract.

Dilatation coefficient. Ovio (*XIX. Congress Ital. Ophthal. Trans.* No. 2, 1907), finds that when the illumination in the eye is gradually reduced, the pupil will dilate with inverse proportion to the light reduction. As the light is reduced the dilatation at first takes place slowly and then with increased rapidity as the light is further withdrawn.

Dilatation due to stimulation of cervical sympathetic. To prove that the sympathetic acting alone will dilate the pupil Anderson (*Jour. of Physiol.*, 1903, p. 50), excised the ciliary ganglion in cats. This paralyzed the sphincter, then by stimulating the spinal cord with the faradic current and by pinching the skin and stroking the hair, he obtained marked dilatation of the pupil. He also divided the cord at the line of the first cervical vertebra and secured dilatation of the pupil by stimulating the sciatic nerve, overcoming the miosis produced by a one per cent. solution of eserin. These tests prove that dilatation of the pupil is due to stimulation of the sympathetic supplying the dilator pupillæ.

If the short ciliary nerves be severed the pupil will dilate but the dilatation will be greater in the same case when the cervical sympathetic is stimulated, and still greater dilatation (ad maximum) can be produced if potent mydriatics are instilled in the eye.

Dilatation reaction. In much reading and research in the preparation of this section the writer has failed to find specific mention of methods for testing the dilatation reaction of the pupils other than by partial shading of the eye in ordinarly light. Many writers refer to the sensory or pain reflex, and also the cortical reflex, as well as the spinal irritation, the cerebral paralysis or nuclear palsy reaction, all of which are expressed in dilatation of the pupils, but so far as he has been able to observe, no one has attempted to formulate a definite clinical test to determine the dilatability of the pupil without the employment of mydriatic drugs. It is manifestly as important from a diagnostic sense to ascertain the reaction of the dilator pupillæ in a given case as to ascertain the reaction of the sphincter pupillæ, to which so much attention and study has been directed. The condition of the sympathetic nerve mechanism is as important to know as that of the pupillary light reflex arc. The usual reaction tests recommended for testing the pupil are: (1) the direct, (2) the indirect or consensual, (3) the convergence and accommodation reactions, all of which appertain to the sphincter pupillæ. We have yet to learn a definite standard test for determining the dilatability of the pupil. The question is, what is the normal dilatability of the pupil in different ages as measured in millimeters?—and what is the range of pupil activity between the limit of normal dilatation in total darkness and normal contraction? The impulse to dilatation is entirely different from that of contraction, anatomically and physiologically speaking, and their pathways are separate and distinct from their nuclei of origin to their nerve endings. The behavior of the pupils in health and disease will not be fully understood or properly interpreted until we have methods of precision to determine the status of the dilating impulse. We believe, for instance, that in brain tumor there is greater dilatation of the pupils in certain cases than will exist in those same cases after death. We know that atropin will dilate a completely paralyzed pupil still further. In syncope we have wider dilatation than can be produced physiologically in conscious states, and wider than in death. There are normal dilatations, paralytic dilatations, irritative dilatations and restricted dilatations. There are dilatations from monocular, or inherent stimuli, and dilatations from referred or consensual stimuli. In testing the pupil reaction we should regard the dilatability as much as the contractability. The significance of the one is as necessary and as valuable as the other. Much is yet undone. In this connection the reader is referred to Kunz and Ohm's experiments in photography of the pupils in darkness (see *Photography* in this section) for the only suggestion the writer knows of that has been made for determining the actual physiological dilatability of the pupil.

Dilating and contracting fibers (pupil), experiments on dogs to demonstrate the course of the. Guirato (*Ann. di Ottalm.*, XXIX, Vol. I, No. 2), experimenting on dogs to determine the course of the pupil-dilating fibers came to the following conclusions: (a) Destruction of the ophthalmic ganglion caused great mydriasis, anesthesia of the cornea and conjunctiva, hypotony of the ball, trophic disturbances and suppuration of the eye. (b) The same effect was produced by cutting all the ciliary nerves. (c) Section of the long ciliary nerves alone caused a moderate miosis. (d) Section of the long ciliary nerves together with extirpation of the superior cervical ganglion of the sympathetic resulted in an excessive miosis. (e) Electrical stimulation of the long ciliary nerves caused excessive pain and marked mydriasis. (f) Electrical stimulation of the short ciliary nerves caused pain and moderate miosis. (g) Electrical stimulation of the superior ganglion after section of the long ciliary nerves dilated the pupil moderately. (h) Section of all the ciliary nerves and stimulation of the sympathetic did not influence the pupil.

Dilator pupillæ in man. In an article by Grunert (*Arch. of Ophth.*, July, 1901, Vol. XXX, No. 4, p. 377), it is stated, the first anatomical description of this muscle was given by Valentine and Bruecke when Koelliker first demonstrated the presence of smooth muscular fibers in the iris.

At that time (1901) there was no doubt regarding the presence and function of the sphincter pupillæ, but as regards the dilator pupillæ there was still considerable question. In making radial sections of the iris a layer of somewhat lighter tissue between the connective tissue stroma of the iris and the pigment layer on its posterior surface was described by Bruch (1844) and has since borne his name. It was noticed as a hyaline, structureless membrane and he contended that it was a continuation of the basal membrane of the choroid which could be followed over the ciliary processes to the posterior layer of the iris. He remarked, however, on the numerous nuclei present.

Henle was the first to give a full description of this membrane (1866). He succeeded in showing the rod-shaped nuclei and he isolated the spindle-shaped cells. These, together with the finely striped appearance of its surface and the distinct fibers that were differentiated, led him to declare that it was a muscular structure and so he considered it to be the dilator pupillæ.

"Bruch's membrane" was renamed "Henle's muscle." Merkel in 1873 still more definitely described Bruch's membrane, or Henle's muscle, as a continuous muscle layer on the posterior surface of the stroma of the iris. According to him it divided into two layers as it approached the sphincter pupillæ, one passing radially to the pupil behind, the other forming peculiar arched connections with the fibers of the sphincter, the separate bundles leaving the radial direction and becoming circular. His discovery and reports were received by some and strongly contested by others. It is not the province of this article to follow the history of the progress that was made.

It is commonly conceded now, for it has been definitely demonstrated, that the dilator pupillæ muscle has its origin in the root of the iris and its insertion somewhat as first described by Henle.

Grunert maintains that it is a sheet muscle, or continuous muscle layer, since it is not absent in any of the radial sections of the iris. This position is denied by Henderson as reported elsewhere in this article. (See *Muscles of the iris.*) Grunert claims there is considerable difference in the elasticity between the anterior and posterior layers of the iris; that the anterior layers composed of loose stroma are not as extensile as the posterior. Moreover, that in miosis the extensibility of the anterior layers is reached first, the consequence being that when the limit of the extensibility of the posterior layers is reached there is ectropion of the pupillary margin. In mydriasis, on the other hand, this ectropion iridis disappears from the greater contraction of the posterior surface of the iris which drags the posterior border a little farther up on its posterior aspect.

Eversbusch (1885) explained the existence of slit-like pupils in certain animals on the ground that the oblique connecting fibers in the iris are not disposed regularly around the circle of the iris, but occur on opposite sides where they fix the ring muscle and draw the pupil lengthwise in contraction states. (See *Cat-like pupils* in this section.)

During mydriasis the iris is emptied of blood and the ciliary processes are filled. The posterior chamber is flattened and the root of the iris becomes cord-like. Because of the deficient muscular tissue in the walls of the blood vessels of the iris the dilator pupillæ assumes the function of a vaso-motor.

Widmark (*Arch. of Ophth.*, Jan., 1901, Vol. XXX, No. 1, p. 107), studied five eyes that were enucleated for sarcoma to demonstrate, if possible, the existence of the dilator pupillæ muscle. He found that the so-called "membrane of Bruch" was composed of very long, closely lying cells containing individual nuclei and that they responded to the same stain as the cells of the sphincter pupillæ and were therefore to be considered as being unstriped muscle cells. Heerfordt in his studies on the dilator pupillæ, published in Copenhagen in 1900, proved the same thing. He noted further that when the pupil is contracted with eserin the cells are separated and are readily distinguished.

A. Alt (*Amer. Jour. Ophthal.*, Sept., 1907), calls attention to the fact that the modern text-book speaks of the dilator muscle of the pupil as an undoubted and well proven entity and give nice and simple illustrations. He states the question is still *sub judice* in-so-far as regarding it as a well defined and distinctly muscular structure.

Henle, Merkel, Luschka, Jeropheeff and others state this membrane consists of unstriped muscular fibers but their antagonists, Gruenhagen, Hampelin, Schwalbe, Michel, Koganei, Fuchs and others describe it as "a structureless hyaline membrane with elastic properties" or as a tissue midway between elastic and connective tissue. Alt himself by the employment of a refined method of staining was among the first to demonstrate separate muscular fibers running divergently from the pupillary sphincter to the root of the iris. They were differentiated as a single row of spindle cells with rod-shaped nuclei and indistinct cell outlines lying anterior to the pigment layer of the iris. He now states,—"Granted then that we have seen and described the musculus dilator pupillæ, it appears that it is rather a weak muscle in comparison with the sphincter pupillæ. It seems, therefore, very probable that its action is enhanced by the contraction of the iris arteries and perhaps by the relaxation of the sphincter muscle whenever dilatation of the pupil takes place." (See *Musculature,* this section.)

Dimension, The physiological pupillary. Schirmer in 1894 reported a series of observations to determine the physiological pupillary dimension. He decided that this dimension can be determined by noting the size of the pupil in a normal individual who is exposed four minutes to the light after coming from a dark room; and also the size of the pupil after the patient is in darkness fifteen minutes. The difference in the size of the pupil noted in the light in mm. and that of the pupil measured in the dark in mm. gives the dimension. He also found that the pupil did not alter its size when light intensity was used between 100 candles and 1100 candles. (See *Normal pupil,* this section.)

Dionin, Effect of. Suker (Chicago Ophth. Society, March 13, 1906) reported the case of a man of twenty-one who had had his eye hit by the explosion of a percussion cap. There was plastic iridocyclitis present. In order to aid in dilatating the pupil he used powdered dionin. Much to his surprise the most pronounced miosis developed. The pupil was hardly visible and it refused to dilate after atropin drops were applied for several hours, even then the pupil only became the size of a pin-hole.

The same powder was used in another patient who had iridocyclitis to see if the same result would follow, but no such effect was produced. Faith had seen a similar case of miosis following the use of dionin.

Dodd had seen slight miosis in several cases following the use of dionin. Loring used a 5 per cent. solution of dionin in a boy whose pupils were fully dilated from several days' use of atropin; fifteen minutes after the dionin was instilled the pupils were contracted to 3 mm. and remained so for about one hour, when they began to slowly dilate. Colburn had produced contracted pupils by means of dionin.

Toczyski (*Zeitsch. f. Augenheilk.*, July, 1912) reports that dionin causes contraction of the pupil and increased intraocular tension at the same time. This lasts about four hours and is followed by slight mydriasis and sub-normal tension. The mydriasis begins to be manifested while the tension is still up.

Rutherford (*Ophth. Record*, Vol. XV, No. 10) claims that dionin combined with atropin and used in cases of iritis, assists in dilating the pupil.

Diphtheritic paralysis. Weisenburg (Posey and Spiller—*The Eye and Nervous System*, p. 605) states that approximately one fourth of the total number of cases of diphtheria is followed by paralysis. As a rule the paralysis does not appear until the active diphtheria has entirely departed. Next to paralysis of the soft palate the most frequent form of paralysis of diphtheria origin is referable to the ciliary muscle. The accommodation is lost.

Weisenburg states the pupils are of normal size and the light reflex is never lost. Since the advent of antitoxin in the therapy of diphtheria we no longer see so many cases of this kind.

The cause of paralysis of accommodation has not been definitely proven. Meyers found a disappearance of the axis cylinders, changes in the myelin and increase of nuclei of the endoneurium of the third nerve, while Wilbrand and Saenger believe the cycloplegia to be due to nuclear or central lesions.

Direct light reflex test. In conducting this test the patient should stand with his face squarely in the light, preferably where there is a bit of sky exposure, but the diffuse light of day is to be used; not the sunlight. It is desirable to avoid the act of convergence or accommodation; therefore the patient is instructed to direct his gaze and attention to an object out of the window at infinity. Then both eyes are covered by the palms of the observer's hands, being careful not to stimulate the skin of the face by the touch (as with cold or wet hands). The eye being tested is then uncovered and the behavior of the pupil noted.

Weeks (Posey and Spiller, p. 299) recommends the following test: "The patient should be placed in a dark room facing and fixing a single source of light. The light should be not more than one meter from the patient. One eye of the patient is excluded from the light by covering it with the hand or some opaque object. By means of a concave lens (15 or 20 D.) the light is now focused in the exposed eye, the patient not being permitted to look in any other direction than in a direct line to the light. The light may be thrown into the eye and out of the eye at the will of the examiner. The position and direction of regard eliminate any influence upon the pupil by accommodation or convergence. The strong illumination of the eye thus obtained makes it possible to determine with certainty the presence or absence of the pupillary light reflex." (See also *Examination of the pupil* in this section.)

Discoria. This implies congenital irregular contour of the pupil. The pupil may be notched on one side, especially downwards, suggesting an abortive attempt to produce a congenital coloboma during the stage of development. In other cases we have slit-like pupil running horizontally, as was observed in a case in the writer's practice. (See *Cat-like pupils* herein.) The condition was present in one eye only. Heterochromia was also present. There was some response to light and the upper part of the pupil dilated shortly after homatropin drops were instilled. Discoria may be present in the cases of persistent pupillary membranes, as previously described.

Dislocation of the lens. (Subluxatio lentis traumatica.) The pupil is often dilated irregularly in traumatic partial dislocation of the lens from (a) shock and consequent paralysis; (b) mechanical pressure and weight of the dislocated lens dragging the lower part of the iris down. In such cases two shades in the pupil space are noted by focal illumination. First, a deep-black crescent between the lens and iris representing the area of actual detachment of the suspensory fibers, and a grayish reflex even when the lens is normal, representing the lens itself which appears grayish. By the ophthalmoscope the red reflex reveals two areas of illumination, one through the dislocated lens and the other through the rupture of the zonule. The edge of the lens shows as a dark curved line separating these areas. (See also *Concussio oculi* in this section.)

Diseases of the ear. Sauvineau (*Ann. d'ocul.*, Vol. CVIII, p. 321) noticed strabismus, miosis and nystagmus in an ear case which he explained as being due to reflex irritation, transmitted from the filaments of the trigeminus, or from the vestibular nerve to Deiter's nucleus and thence to the nucleus of the ocular muscles involved.

Economic value of the size and shape of the pupil. While it is granted that the smaller pupil affords increased acuity of vision in a given case as compared with a dilated pupil in the same case, the fact remains that good, even perfect, vision does not in any way depend on the size, shape or even location of the pupil. The pupil after injuries and cataract extractions, etc., may be very much displaced, even beyond the center of the cornea in any direction. It may be any shape from a mere slit to a wide coloboma.

The necessary prerequisite, however, is that the axis of vision, wherever it may be displaced, shall be unimpeded by scars and astigmatic and spherical refractive errors. After the cataract operation the round pupil is a source of much gratification to the operator, but the patient's vision is in no way improved on account of the pupil being round. A U-shaped pupil or any other will give just as good vision, granted that the pathway of vision is clear.

Much disappointment has followed the performance of optical iridectomy to produce a clear pupil to the side of a central macula of the cornea. The fact that the patient will continue to use his old visual axis that is directed through the scar, even after a clear space is created to one side, is often overlooked. If, however, the central opacity is tattooed the patient will soon learn to use the new visual axis.

Another source of disappointment is that the cornea after an optical iridectomy is often found to be affected with a diffuse macula that had been undetected until the black back-ground produced by the coloboma was created. Nevertheless much good has resulted from the performance of optical iridectomy in selected cases.

Ectropion of uveal pigment (pathologic). Stern, investigating ectropium of the pigment of the pupillary margin, examined four specimens microscopically in which the ectropium of the pigment had been acquired from traumatism. The traumatism was most intense in the deeper structures of the eye, some having detached retina and others grave uveal lesions. There was a growth of pigment epithelium all around the pupillary margin. The root of the iris was adherent to the cornea and there was atrophy of the iris tissue. Other changes noted were marked sclerosis and obliteration of the blood vessels of the iris, hemorrhages in the anterior chamber and also hypertrophy of the sphincter muscle of the iris. From these anatomical investigations he reached the conclusion with regard to the pathogenesis of the ectropium uvea, that the lesions of the vessels caused disturbance of nutrition of the pigment, which, in turn produced augmentation and exuberance of the cells resulting in heaped-up masses of pigment around the pupil margin.

Masses of pigment in the pupil margin resembling melanoma have been observed by Risley (*Ophth. Record,* June, 1911, p. 312). They are apparently only aggregations of the normal marginal pigment cells, similar to the condition found in the pupils of horses' eyes and are of no apparent pathological significance.

He mentions the case of a young woman who had a large pigment mass on the nasal side of the pupil which produced not the slightest irritation. The condition is sometimes called "ectropium of the retinal pigment." There should be a clear distinction between congenital ectropium of the uveal pigment and the acquired form. The latter is a progressive lesion that is often of grave import, while the former is a physiological (embryological) peculiarity.

Edinger-Westphal nucleus. "The nucleus of the motor-oculi nerve lies below the aqueduct of Sylvius. This group of cells consists of a median nucleus with a lateral nucleus on each side of it. Anterior to these a group of small cells is found on each side of the median line and is known as the Edinger-Westphal nucleus."

It is this nucleus that is supposed to supply the impulse to the sphincters of the ciliary and iris; it is not, strictly speaking, a part of the third nerve as it is composed of an independent nucleus and fibers, the former of which, as above described, is independent and the latter pursue an independent course and distribution. Nevertheless, the centers for innervation of the convergence lie so close to the centers for accommodation and pupillary contraction that they act as one, for the acts of convergence, accommodation and pupil contraction are rarely disassociated.

Eel serum, Effect on the pupil of. Steindorff (*Archiv. f. Ophthal.*, LXXXVIII, p. 158), experimenting with eel serum, reports that the intravenous injection of this serum in animals produces a very intense miosis. The miosis is greater than that produced by eserin and does not yield to atropin. It does not occur in immunized animals and the serum is rendered inert as regards its miotic effect on the pupil by boiling or treating with ultra-violet light. The cause of the miosis is not known.

Eel serum dropped in the eye incites an intense conjunctivitis.

Embolism of the central retinal artery, Pupil reaction in. Tyson (*Arch. of Ophth.*, January, 1902, Vol. XXXI, No. 1, p. 68) reports a case of embolism of the central artery of the retina with the preservation of a small patch of sight in the macula owing to the presence of a cilio-retinal artery. In this case the pupil of the affected eye was larger than the other and reacted sluggishly to light and accommodation. When this eye was illuminated the pupil of the other eye reacted promptly, but when the other eye was illuminated the pupil of the affected eye reacted slowly and partially.

This is interesting as going to prove that there is a direct relation between the pupillary fibers and the visual fibers as regards their distribution and arrangement in the retina. It also is an argument in rebuttal of Hess' recent declaration that the macular region in an area of 6 mm. in diameter is the only place where the pupillomotor fibers exist. If Hess' theory were correct one would expect Tyson's case to show a normal reaction of the pupil. This argument is further substantiated by the response of the pupil unquestionably found in coloboma of the macula lutea with absolute central scotoma or complete destruction of the macular region. (See *Retina* in this section.)

Enophthalmos, Traumatic. Van Schevensteen (*Ann. d'Oculiste*, Dec., 1909) discusses traumatic enophthalmos and states that the disease is not the result of injury to the sympathetic nerve, as believed by some. The absence of contracted pupil argues against sympathetic involvement, for in sympathetic paralysis the pupil is always found contracted. In the cases of enophthalmos that have come to the notice of the present writer there was always diagnosed a fracture of either the inner wall or the floor of the orbit, and the opinion was formed that the orbital fat had herniated into the ethmoid labyrinth in the former case or the antrum of Highmore in the latter. The pupil in one case was dilated and fixed and the cornea was completely anesthetic. The inference was that the function of the ciliary ganglion in this case was destroyed.

Epilepsy. During the epileptic fit the pupils are widely dilated and do not respond to light. This fact has proven of great value in its medico-legal aspect, and also in diagnosing malingering, hysteria, etc. But Gowers and Onuf have noticed that in the majority of cases there is extreme contraction of the pupil at the very onset of the attack and also that the pupils are contracted in the post-convulsive stage. During the attack, however, the pupils are wide and fixed. After the attack, and during the exhaustive stage which follows, the pupils may exhibit marked oscillations. These oscillations are in the nature of alternate contractions and dilations, but are not always present. If the cases of epilepsy are associated with gross organic lesion ("symptomatic" epilepsy) the pupils may exhibit abnormal features independent of the epileptic crisis—features due to the nature and location of the cerebral lesion present.

Oliver, of Philadelphia (*Ophthalmoscope*, May, 1905), examined the eyes of sixty epileptics and made the following observations as regards the pupils. (1st) that the pupils were usually oval or ovoid with their long axes slightly downward and outward. (2nd) The pupils as a rule were unequal in size, that of the left eye being generally the larger. This observation agreed with that of Browning (*Jour. Nerv. and Ment. Dis.*, Jan., 1892), who first called attention to anisocoria in epilepsy, and (3rd)the borders of the pupils presented unusual pigmentary aggregations.

Eserin, The effect on the pupils. Risley (*Ophthalmology*, April, 1915, Vol. XI, No. 3, p. 455) states that eserin increases the irritability of both striped and unstriped muscle fibers, the effect apparently being due to the stimulation of the peripheral nerve endings. It causes marked contraction of the pupil by stimulating the peripheral endings of the oculo-motor nerve and probably also of the iris muscle itself; and Cheney (*loc. cit.*, p. 458) observes that eserin has a favorable effect on glaucoma independent of its miotic action. He reports a case where there was atrophy of the iris with dilated pupil which was not influenced by eserin and yet the tension of the eye was reduced by its use.

It has been observed that the use of a strong solution of eserin may incite a fulminating attack of glaucoma with dilated pupil, instead of contracting the pupil and reducing the tension. The explanation offered for this is, that the irritating effect of the pungent solution causes a primary congestion of the iris which locks the efferent channels through swelling of the iris tissue and in this instance the miotic effect of the drug is entirely overwhelmed and lost.

Eserin, Localizing value of. Krusius (*Zeit. f. Augenh.*, Nov., 1907), assuming that Shultz was right when he stated that eserin produces miosis by stimulation of the nerve-endings in the sphincter, argues that the drug should, if that were true, be of value in determining the location of a lesion causing mydriasis as to whether that lesion was anterior to the roots of the ciliary ganglion or posterior to that ganglion. To determine whether such could be proven he applied the drug in cases where the degeneration was known to be anterior to the roots of the ciliary ganglion and where the condition was of long standing. Prompt miosis resulted and hence he declares that in this connection eserin has no diagnostic value. On the other hand it is generally known that in complete atrophy of the muscle tissue of the iris, as noted in some cases of long standing glaucoma, eserin has no effect on the pupil.

Essential mydriasis. Magnani (*Arch. of Ophth.,* Nov., 1904, Vol. XXXVIII, No. 6, p. 591) remarks that the pupil is under the control of two different nervous impulses. One presides over reflex movements (light reflex and sensory reflex) and the other over the reactions associated with convergence and accommodation.

In a boy aged 20, presenting a partial dislocation of the lens (the result of concussion), with irregular mydriasis the pupil did not react to light but during the convergent effort a marked contraction of the pupil was produced. Later on the pupil responded to the light but it never resumed the natural size. There are many observers who have found similar symptoms. He calls the phenomenon "essential mydriasis."

Ethmoiditis, Pupil behavior in. A. Knapp (*Trans. Am. Ophthal. Soc.,* 1908) reported a case of double optic neuritis following suppurative ethmoiditis in which the pupils were small, irresponsive to light and in a condition of hippus. The patient did not have perception for light. The contraction of the pupil in this case is difficult to account for unless we assume that the ciliary ganglion and also the sympathetic nerves in the orbit were affected reflexly from the ethmoid inflammation.

Euphthalmin as a mydriatic. A. W. Calhoun, of Atlanta (*Ophthal. Rec.,* January, 1902, Vol. XI, No. 1, p. 43), writing on euphthalmin as a mydriatic, states,—"Euphthalmin in 5 to 10 per cent. solution is an excellent and powerful mydriatic, dilating the pupil in fifteen to twenty minutes sufficiently for ophthalmoscopic examinations, and in thirty to forty minutes to its maximum. At the end of twenty-four hours the return of the pupil to normal is complete. On account of its brevity of action it is superior to any other mydriatic; in fact it is without a rival for dilating the pupil for diagnostic purposes. It affects the accommodation only very slightly and no unpleasant systemic effects have been observed, but it is known to act less promptly in the aged than in younger persons.''

Examination of the pupil. Coppez (*Arch. d'ophtal.*, Vol. XXIII, No. 2, p. 85) gives an account of the anatomical and physiological relations concerned in pupillary disturbances and recommends a definite procedure in examining the pupil. The light reflex is tested by daylight. The patient is directed to look at a distant object for two minutes through a well-lighted window. In this test the pupil should measure between 2 and 4 mm. in diameter, according to the age of the patient. Any departure from this size suggests disturbances. The reaction to light is then tested in the usual manner. First, the direct, then the consensual, and lastly the convergence reaction. If the pupils are unequal in size further tests are made in a dark-room where this inequality becomes more pronounced.

In order to determine which is the pathological pupil, cocain is used. If the larger pupil does not dilate after cocain solution is dropped in the eye he regards it to be a case of mydriasis due to excitation of the dilator fibers. If there is further dilatation from the cocain drops he regards it to be evidence of paralysis of the sphincter pupillæ, but if there is moderate dilatation with cocain in the eye presenting the larger pupil he interprets this to be the normal behavior and regards the other pupil to be pathological. In the eye presenting the contracted pupil atropin drops are used. If the dilatation is slight, he regards it to be a case of paralytic miosis. If the dilatation is marked he regards it to be a case of spastic miosis.

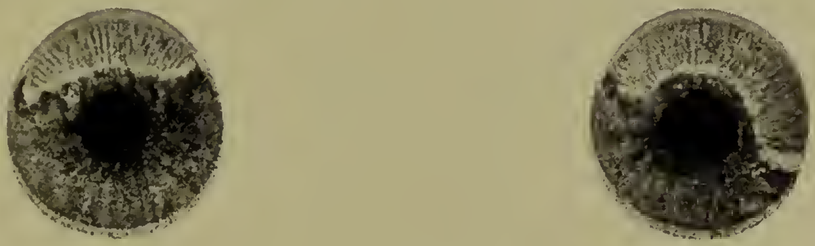
Exsanguination blindness, Pupils in. In severe hemorrhage when the patient faints from the loss of blood, he will often complain of total blindness before losing consciousness. The pupils in this state are always dilated and immobile to light. Sometimes the blindness is not associated with cardiac failure. Cases have been reported where there was transient or even permanent blindness due to the loss of blood. It is not known what causes the blindness in these cases, whether there is anemia of the visual centers in the cuneus or whether there is ischemia of the retinæ and optic nerves. The return of vision is accompanied by return of pupillary response, but during the period of total blindness the pupils are widely dilated and fixed.

Exfoliation of the iris. Jackson (*Ophth. Record,* August, 1900, Vol. IX, No. 8) reported an interesting case of exfoliation of the iris in a man of 44. The pupils were free and reacted in a normal manner, proving that the musculature was not involved.

An observation which Jackson did not mention is, that in the carefully executed colored drawings that accompany his report one can see the radiating fibers of the dilator pupillæ on account of exfoliation of the outer layers of the iris stroma. (See illustration.)

Exhaustion, Abnormal, of the pupillary light reaction. Kutner (*Arch. f. nerv. u. psych.*, XXIX, p. 825) observed a man of 26, in whom the pupil of the right eye reacted to the light and was wider than the left, but after making the test from eight to fifteen times, the pupil seemed to become exhausted and would not react singly nor consensually. The response to light returned after a thirty minutes rest in darkness.

Exophthalmic goiter. The pupils in exophthalmic goiter usually respond to the light and appear normal. The writer has noticed that they are slightly larger than normal. The prominence of the eyes must permit more light to enter through the pupil and we would expect some contraction instead of dilatation. We must consider, too, that exophthalmic subjects respond to other stimuli almost abnormally. The influence of hyperthyroidism on the sympathetic, and also of mechanical pressure or stretching of this nerve from the enlarged gland, may in some cases affect the size and behavior of the pupils.



Right. Left.

Showing Dilator Pupillæ.
Exfoliation of the Iris. (Jackson.)

Family irideremia. Palmieri (*Annali. di. Ottalm.*, fasc. 5-6-7, 1912) observed three typical cases of congenital absence of the iris in members of the same family. The mother 46, her daughters, 26 and 24, respectively, presented this same congenital peculiarity. They all likewise suffered from cataract, nystagmus and glaucoma. Other families similarly affected have been reported. (See *Coloboma familias* in this section.)

Family pupillary difference. Paterstein (*Berl. Ophthalm. Gesellsch.*, June, 1913) observed a family of five members in each of whom a difference was noted in the size of the pupils. The reactions were normal. The differences noted were physiological.

Form of the normal pupil. Kanngieser (Knapp's *Archiv. of Ophth.*, Vol. XL, No. 2, p. 202) studying the contour and position of the pupil in two hundred normal persons found only five that presented variations from the circular form; in these the pupils were longitudinally oval. Among twelve of the two hundred he found finely notched pupillary margins chiefly in old people. In two instances only were the pupils noticeably different in size. Four presented remains of pupillary membrane but ten others had tiny bosses of pigment extending in the pupil space from the free border of the iris.

Friedreich's disease. The pupils are normal in size and reaction in this disease, but in cerebellar ataxia, which presents very similar nervous symptoms to Friedreich's disease, loss of pupillary reflex reaction to light is rather frequently present and owing to the pathology being located not far from the medulla where the center for pupillary dilatation exists, there is sometimes found in cerebellar ataxia, typical Argyll-Robertson pupils. The different characters of the pupils in these two clinically similar diseases should aid greatly in the diagnosis.

Function of the pupil in health. The pupil is designed for the following main purposes:

(1) To allow the passage of rays of light to the bottom of the eye to stimulate those recipient elements of the retina which are concerned in the special sense called "sight" and at the same time to afford a return outlet for projection and orientation.

(2) By contracting and expanding to control that quantity of light entering the depths of the eye which is nicely required to give the proper stimulation to the elements of the retina and subserve the purposes of the special sight sense.

(3) To aid in sharp vision for differentiation by contracting and cutting out the rays of light that would otherwise pass through the sloping sides of the lens that lie behind the iris, or, in other words, to aid vision by dispelling spherical aberration. This function is insistent.

(4) To afford a highway through which the conscious living animal may acquaint himself with objects beyond the scope of his other senses, for his pleasure, self-preservation and the perpetuation of his species.

The pigmented iris performs, then, a two-fold physiological function both of which, by the way, are somewhat fanciful. First,—The automatic physiological action of the pupil whereby it dilates in the dark and contracts in the light and which is adjusted in beautiful adaptability to the needs for clear vision. Second,—The pupil contracts with the effort at accommodation to objects close to the eye. This greatly aids the vision. Occasionally we meet with persons past fifty years of age, and some near sixty, who have 20/20 distance vision and also read fine print at the ordinary distance near-by without lenses.

Such persons possess small pupils, either natural (senile), or pathologic (miosis), and in them the circles of diffusion from the lateral rays which pass through the edge of the pupil are intercepted allowing the axial bundle of rays to enter. The axis ray is the only one that is not refracted and it gives clear vision for the reason that it passes into the very fovea centralis. But these two accepted functions of the pupil, viz., to shutter the retina from excessive light and to increase the acuity of vision, are curiously proven fanciful when we recall that in cases of iridcremia the patients become accustomed to the light and do not complain of photophobia to any great extent, while we are repeatedly reminded of their ability to read the finest print with comfort and ease. This is also true in mydriasis with cycloplegia for we find the patients can read perfectly well with a plus 3.0D. lens added to their correction. There is no question, however, that the evil effects of ultra-violet rays or intense radiant energy on the retinal elements are greatly thwarted by the contracted pupil. Natives living in the tropics have dark irides which is nature's contribution to shutter the excessive glare in these torrid regions.

Fusion (binocular) of one's own pupils. Kahn (*Arch. f. d. ges. Physiologie,* Vol. CXLV, p. 249) states that a binocular union of one's own pupils may be readily produced by looking in a mirror with parallel visual axes. There are three images noticed in the mirror. The middle or cyclopic image has two inner canthi and one pupil.

Galassi-Gifford palpebral reaction of the pupil. Gifford (*Arch. of Ophthal.,* March, 1900, Vol. XXIX, No. 2, p. 191), discussing the history of his discovery that the pupil contracts when the palpebral portion of the orbicularis forcibly contracted (1888), states that it was rediscovered by Westphal in 1899 and apparently also by Piltz in the same year. Piltz (*Neurolog. Centralbl.,* 1899, 6) mentions Gifford's discovery but claims priority for Wundt. Gifford states that Wundt did not make the same observation regarding the reaction that he had reported and therefore did not anticipate him. Wundt's language was as follows: "Light stimulus regularly causes a double reflex, first, a closing of the eyelids with a turning of both eyes inwards and upwards; and, second, contraction of the pupil," but this contraction is only the ordinary light reaction.

Gifford grants that Galassi preceded him in his discovery, for in 1887 (*Bulletino della Soc. Lancis,* etc., Vol. VII, No. 6) Galassi reported "a new pupil reflex" in two women with oculomotor paralysis. "The pupil was slightly dilated and fixed to light and convergence, but if the patient closed the eyes firmly, the pupil of the unaffected eye contracted sharply." Similar tests repeated on healthy subjects led to the corroboration of the discovery that the contraction of the pupil to forcible closing of the eyelids is a normal reaction. Galassi subsequently reported the case of a woman with fixed mydriasis from third nerve palsy who exhibited an exaggerated contraction of the affected pupil to this test. The fact that this reflex persists in peripheral lesions of the third nerve when all other pupil reflexes are gone, may be used to differentiate between central and peripheral lesions.

Gifford calls attention to the fact that the reaction will not occur unless the orbicularis palpebrarum is employed. The contraction of the brow (corrugator supercilii) together with contraction of the cheek muscles can occur without action of the orbicularis and the reaction fails in this case. After the contraction of the pupil in this test there occurs a momentary dilatation. (See *Westphal-Piltz* in this section.)

Galvanic-light reflex. Bumke (*Zeit. f. Psych. u. Phys. d. Sinn.*, XXXVI, 4, p. 294) demonstrates that galvanic-light stimulus applied to the eyeball, produces reflex pupillary contraction and applies the test in differentiating the direct and consensual reaction by determining the minimum of stimulation required to elicit response. In many cases the test was of no determining value, but in other instances, as in conditions of exhaustion, the sensibility to galvanic-light was increased while the effect on the pupil response was diminished.

Ganglion, The pupil in removal of the superior cervical sympathetic. Burghard (*Brit. Med. Jour.*, Oct. 20, 1900) reports that in a case after sympathectomy the pupil did not contract. In another case after removal of the ganglion along with a new growth in the glands of the neck, the pupil on that side immediately contracted and it also reacted to the light. In a third case where the middle and superior ganglia were removed for a tumor in the neck, there was immediate contraction of the pupil.

It was the hope of ophthalmic surgeons over ten years ago that the removal of the superior cervical sympathetic ganglion in cases of glaucoma would work a cure of the disease. The hope grew out of the discovery that after ganglionectomy the pupil of the eye became at once somewhat reduced. Other symptoms, such as partial ptosis, enophthalmos, ocular congestion, local hyperidrosis, etc., occurred. The miosis did not last longer than a few weeks and the increased tension in glaucoma returned so that this surgical procedure has fallen into disrepute. (See *Sympathectomy* in this section.)

Glaucoma, Anomalous condition of the pupil in. Several observers have found glaucoma in the presence of contracted pupil. Coover

(*Ophth. Record*, April, 1908, Vol. VII, p. 4) mentions such a case and states that the contracted pupil was due to synechia.

Strickler (*Ophth. Record*, January, 1913, Vol. XX, No. 1) noticed that the pupil was smaller in a glaucomic eye than in the other which was normal. The tension was raised to 52 mm. In the discussion Jackson reported a similar case in which the pupil was only a little dilated. It is probable that Strickler's case had a mild iritis causing the contracted pupil.

Fernandez (*Archivos. de. Oftalmolog.*, June, 1905) observed the contracted pupil in three cases where there was inflammatory glaucoma. The pupil was not only contracted, but also fixed; it was slightly oval in contour and appeared very much like the pupils we see in iritis.

Glaucoma absolutum. In glaucoma absolutum there is marked atrophy of the iris. Sometimes the red reflex can be seen through the iris tissue. The pupils are always dilated and fixed on account of complete atrophy of the iris. In these cases eserin has no effect in contracting the pupil. The muscular fibers of the iris have disintegrated.

Glaucoma, Incipient. Bradburne (*Ophthalmology*, April, 1911, Vol. VII, No. 3, p. 384) writing on incipient glaucoma states that the increased intraocular pressure acts upon the iris in two ways: (1) By the direct effect upon its vessels and nerves. (2) By causing it to become displaced forward owing to the forward push of the lens upon which it rests.

This double effect enlarges and weakens the action of the pupil. He also states that the pupil in glaucoma is dilated partly because of the adhesion at the root of the iris which also accounts for the oval pupil frequently seen in glaucoma.

Glaucoma, Incipient, Mydriatic drugs in diagnosing. Euphthalmin has been used intentionally in eyes that presented signs of incipient glaucoma, for the purpose of establishing a diagnosis, by H. Knapp (see *Archiv. of Ophthal.*, Vol. XXIX, No. 3). The writer was in Knapp's office at that time and remembers the case very well. Tonometers were not in use in those days and palpation was the sole means of determining plus tension. The patient presented no evidence of plus tension by palpation, but did present other evidence of incipient glaucoma. Knapp intentionally instilled euphthalmin to dilate the pupil and incite an attack of glaucoma for diagnostic purposes, maintaining that it was safer for the patient to have the attack in his office than elsewhere. Euphthalmin promptly dilated the pupil and induced a +1 tension; she was operated on a few days later with success.

Since the advent of tonometry in routine practice, Knapp's euphthalmin test is hardly justifiable; it reveals, however, the relation between dilatation of the pupil and glaucoma. It is mentioned in many text-books that anxiety, emotion, fright and other profound mental states have a tendency to incite glaucomic storms in predisposed patients. The effect on the pupil in these cerebral states is to produce dilatation through cortical action and the glaucoma declares itself as the consequence of thickening of the root of the iris from dilatation.

Bach states that "the well-known dilated sluggish pupil" was of value in diagnosing two cases in which the central vision and fields were still normal.

Glaucoma, Acute inflammatory. In all forms of inflammatory glaucoma the pupil is dilated and is either immobile or sluggish in reaction. This may be in part due to the obtundity of the retina on account of the intraocular pressure whereby the vision is lowered and the pupillomotor nerve fibers are inhibited, and also in part due to the hazy media in glaucoma which shutters the volume of light. The contraction of the pupil brought about by eserin drops in cases where the iris tissue is not atrophic very often results in tiding over the attack so that the size of the pupil in inflammatory glaucoma is a very good index as to the state of the eye and the progress of the disease.

The increased intraocular pressure causes paralysis of the sphincter pupillæ and so the consensual reaction of the pupil is inhibited. The direct reaction is also inhibited. The forward crowding of the iris from the forward dislocation or position of the lens in this disease tends, in itself, to dilate the pupil.

Glaucoma simplex. Many cases of glaucoma simplex do not present any dilatation of the pupil that is conspicuous; at least, dilatation is not one of the necessary signs of the disease in the early stages. The field of vision becomes encroached on the nasal side and the retina on the temple side becomes atrophic. The pupil will sooner or later show some dilatation so that the state of the pupil in glaucoma simplex is a very good index as to the extent and progress of the disease. It seems to dilate and lose its ready response apace with the encroachment of the visual field and will respond to light slightly even when only a small patch of live retinal fibers exists on the nasal side of the retina which permits seeing hand movements in the temple field. (See *Tension*, this section.)

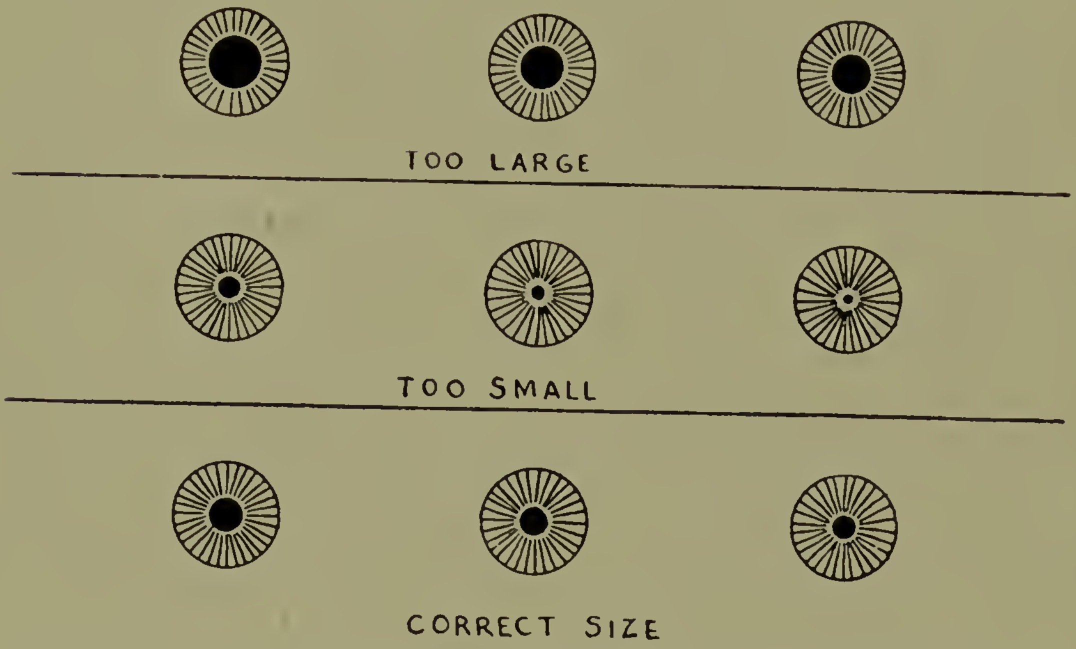
Glaucoma simplex, Myotics in. Posey (*Trans. Ophth. Sect. A. M. A.* 1906) enters a plea for the continuous and intelligent use of myotics in the management of glaucoma simplex. He has found that eserin or pilocarpin in proper strength to keep the pupil well contracted was successful in halting the progress of the disease, as regards its effect on the vision, for long periods of time, in one case over twelve years. He also advocates the use of weak solutions of these myotics in the fellow eye that may show only a slight tendency to the disease. Since that time (1906) the world has witnessed a furore of operations (trephining, cyclodialysis, sclerotomy, sclerostomy, aqueo-plasty, silk thread drain, muleshoe drain, etc.) for the relief or cure of this disease, but the following of Posey's teaching as to the value of myotics properly used *in this form of glaucoma* affords as good results as any known operation up to this date and is far less risky.

The writer of this section has been in the habit of instructing the family of the patient afflicted with glaucoma simplex to employ the solution of eserin or pilocarpin, not by following a rule of the clock but according to the condition of the pupil, which varies greatly in this disease. The solution of eserin (1 grain or ½ grain to the ounce of water) and pilocarpin muriate (1 grain or 2 grains to the ounce of water) are prescribed and a slip of paper containing the following graphic description is handed to whomever is in charge of the home-management of the case (see figure).

Moreover it is suggested that during the sunny hours of the day the bright light alone suffices to keep the pupils sufficiently contracted and that during these hours the disease is not progressing, but that as the light of day dies out, and especially during the sleeping hours, the pupils dilate under the influence of the increased pressure aided by the darkness and the disease progresses most during these hours. Therefore the myotic remedies are to be used on dark days, in the twilight hours and during the night time sufficiently often and of sufficient strength to maintain contracted pupils according to the third or ''correct'' diagram shown. To do this it is usually only necessary to disturb the patient to employ the drops once during the night, either at midnight or at one o'clock A. M. During the subdued light of the waking hours the remedy may be required as often as every four hours.

Posey (*Jour. A. M. A.*, July 18, 1914) again lays stress on the great value of myotics in this disease and states they should be relied on in the cases presenting no exacerbations. To gain the full benefit, myotics should be properly used. Beginning with doses small enough to avoid creating spasm of the ciliary muscle and rapidly increasing the strength until the pupil of the affected eye is strongly contracted, this contraction should be maintained as long as life lasts, using the proper strength at intervals of three or four hours.

Glioma. The eye with glioma of the retina is usually blind and the pupil is consequently found to be dilated and fixed but in the early stage there is consensual reaction. When the glioma causes increased tension this consensual reaction is lost. The growth may be plainly seen through the dilated pupil and crowding the lens. It presents rather a characteristic pinkish tint which is due to its vascularity. The color of pseudo-glioma is more apt to be grayish in case of congenital mesoblastic mass while after suppurative choroiditis the color of the exudate in the vitreous is apt to be yellowish; moreover in the latter there is tendency to phthisis bulbi (minus tension, salmon-colored sclerotic, etc.), while in the former there are other signs of congenital microphthalmos.



Vail's Scheme to Instruct the Family How Much to Keep the Pupils Contracted in Glaucoma Simplex.

Glioma (Pseudo). The pupil in pseudo-glioma of the retina is usually immobile and three-fourths dilated. The reflex seen by daylight inspection may be greenish-yellow, or pinkish-gray and seems to shine by its own light, producing a striking appearance which even the most ignorant mother will notice. The appearance of the pupil is very similar to that in true glioma. These eyes are often unnecessarily enucleated.

Velhagen (*Klin. f. Aug.*, 50, Vol. II, November, 1912, p. 580) noticed in the microphthalmic eye of a child of seven weeks, a yellowish reflex from the pupil which had been observed by the parents three weeks after birth. It was located just behind the lens and blood vessels were visible in the growth. The eye was enucleated and the growth was found to be a pseudo-glioma. There is nothing which the pupil presents or which can be seen in or behind the pupil that will lead to a correct differential diagnosis between true and pseudo-glioma. The diagnosis must be made from other clinical manifestations (advancing growth, congested eyeball, the incidence of glaucoma, etc., declare for true glioma).

Glycosuria, Diagnostic value of adrenalin acting on the pupil in. An editorial in the *Jour. Amer. Med. Assn.*, June 5, 1915, refers to the mydriasis induced when epinephrin solution is instilled in the eye after resection of the superior cervical sympathetic ganglion, as demonstrated by Meltz of the Rockefeller Institute for Medical Research in 1904. It seems that the miosis induced by paralysis of the sympathetic is speedily and totally overcome by the action of epinephin (adrenalin) so that the pupil will in this condition dilate *ad maximum* while under the influence of the drug.

Loewi in 1908 also observed mydriasis after instillations of epinephrin in the eyes of animals which had had their pancreases excised so that he was led to believe that the pancreas exerts an inhibitory influence on the sympathetic system which influences the sympathetic nerve supplying the dilator pupillæ.

The value of these observations lies in the fact that while in the normal eye adrenalin will not influence the size of the pupil, in certain pancreatic diseases, e. g., those associated with diabetes, the instillation of adrenalin *induces a prompt mydriasis.* This was found to be true in several cases so tested by Loewi.

It was next determined that Loewi's mydriatic reaction could be induced in all conditions where there was excess of sugar in the body fluids. This last discovery tends to subvert the value of the test as a pathognomonic sign of pancreatic disease associated with diabetes. (In phlorizin diabetes the Loewi phenomenon cannot be obtained.) Reports as to the value or reliability of this test as a practical one are lacking. (See *Adrenalin* in this section.)

Haab's cortical reflex of the pupil. Haab (*Arch. of Ophth.*, November, 1904, Vol. XXXIII, No. 6) states that he first mentioned his discovery of the pupil behavior under certain conscious mental efforts in 1885, and again in 1891. The reaction of the pupil which he then noted, and which is now known as "Haab's reflex," is described in his own words as follows: "If in a room illuminated only by light of a candle flame, the light is placed so that it will shine laterally into a person's eyes when he looks directly forward into the darkness, a marked contraction of both pupils takes place whenever his attention is directed toward the light with no change in the position of his eyes. As long as the attention is directed on the light and the fixation of the eyes on the dark wall is maintained, the pupils remain contracted, but as soon as the attention is transferred to the point of fixation they dilate although the quantity of light entering the eye has remained constant and all movements of accommodation and convergence are excluded."

Haab states that we certainly have to do with a reflex in this test which originates in the cortex rather than in the lower centers, like the usual reflexes to light, accommodation and convergence.

This test can be carried out on one's own self by two methods. First: the *entoptic test of Haab* to demonstrate cortical reflex of the pupil. The subject must possess freely movable pupils, and not be senile. A lamp is placed in a dark-room so that the light will fall in the eyes at an angle of 45 degrees. A card with a small hole in it is held half an inch in front of the eye which is more distant from the lamp, while a large sheet of white paper is hung vertically before the eyes at the same distance as the light itself, and in such a way as to permit it to be fairly well illuminated; both eyes are now directed towards this sheet of paper; the entoptic picture of the pupil will then appear as a little bright disk. If the attention is now directed to the light that shines in the eye while the eyes are looking straight ahead at the white sheet of paper, the little bright disk is immediately seen to become smaller, but this contraction does not last very long, until after one has acquired sufficient practice in concentrating his attention on the light and also at the same time on the little bright disk, because the attention is distracted from the light by observing the size of the little bright disk. (See *Subjective test of pupil reflex* in this section.)

Second: With a mirror which is held in front of the eyes while the light is placed at an angle of forty-five degrees to one side and the eyes are fixed on the reflection of one pupil in the mirror. A concave mirror will give the best result on account of the larger image. The quantity of light must be carefully adjusted because if too small the pupils will be invisible and the test will not be demonstrable. The light should fall in one eye only, which permits the other eye to observe the pupil in the reflection. If now, the observer will concentrate his attention on the light which is at one side, he will notice a contraction of his pupil; if he directs his attention on the darkness of his pupil as seen in the mirror it is seen to dilate, only to contract again when the attention is shifted to the light. The same test holds good if the light is held above, below, or to either side.

The pupils act consensually and the amount of contraction is proportionate to the degree of illumination. The influence of accommodation and convergence are entirely ruled out, because of the fact that the eyes are held quietly in one position, and the eye does not accommodate to objects at one side. The light and the white paper are held at the same distance from the eye to rule out any possibility of accommodation.

There is no doubt the test demonstrates the cortical reflex of the pupil because all other influences are stable.

Haab maintains that this test proves that descending fibers run from the cortex to the oculo-motorius, the stimulation of which is transmitted through the pupillary fibers. This is not to be wondered at for it is similar to other connections that we know must exist between the cortex and nuclei.

Haab undertook to find a clinical value to his test and came to the conclusion that in certain diseases of the brain we can, by this test, sometimes glean valuable information. He found the test would not apply in cases where the pupil was sluggish, as in tabes, general paralysis, etc.

Health and disease. Stieren (*Penn. State Med. Soc. Trans.*, September, 1911) discussing this subject states that section of the third cranial nerve causes dilatation of the pupil, due to paralysis of the sphincter, and stimulation of this nerve contracts the pupil; while section of the cervical sympathetic causes contraction of the pupil by paralyzing the dilator, and stimulation of the cervical sympathetic causes dilatation of the pupil—as do also certain emotions that act on the sympathetic system. The pupil of a normal eye will contract when light is thrown upon it, no matter what portion of the retina is illuminated. The reaction of light is always symmetrical, though the illuminated pupil usually becomes smaller than the one remaining in the dark. In tabes and in general paralysis, the light reflex is often abolished although the pupils at the same time react to accommodation and convergence. This syndrome is known as the Argyll-Robertson pupil. For the light reflex to be present and the convergence reflex absent, is a condition that occurs but rarely. Among the other pupillary reactions an important aid to the diagnosis of lesions of the optic tract is Wernicke's pupil reflex.

The pupils of healthy individuals are usually symmetrical in size and shape. They are larger in childhood than in old age. Dilated pupils in the aged, or contracted pupils in the young, when not due to local ocular trouble or to drugs, calls for a thorough examination of the nervous system. A considerable deviation in the normal position of the pupil often occurs after cataract operations. The condition of the pupil during the administration of chloroform is all important, as dilatation under complete narcosis with no response to light or accommodation is a danger signal.

In the discussion, Posey stated there were several phases to the subject that seem to merit special mention. One is the aid that the pupil gives in diagnosing paresis. Inequality or irregularity in the size or shape of the pupils in an adult, with perhaps some slight disturbance in their reaction to light, either directly or indirectly, should always awaken the suspicion of paresis; or, if paresis be not the nervous lesion, some other equally important disease of the cerebro-spinal system may be present. He mentioned the case of an apparently healthy young man who came for the correction of an error in refraction. The presence of a persistent irregularity in the size of his pupils at various times awakened the suspicion of some trouble with his central nervous system. Further inquiry elicited the fact that he was the subject of epilepsy. "We all know that pupillary signs often antedate all other symptoms of tabes. The aid that the pupil may give in making the diagnosis between tabes and cerebrospinal syphilis, a differentiation that is not always easy, is not so generally recognized. The Argyll-Robertson pupil is generally indicative of tabes. Unilateral ophthalmoplegia interna, of syphilis. Inequalities in the size of the pupil and disturbance in the reaction are found in the early stages of cerebral syphilis, often associated with optic neuritis; while palsies of the extraocular muscles, as a rule, belong to the later stages. When syphilitic palsies do occur in the early stages, they develop more gradually and persist longer. Tabetic palsies manifest a tendency toward speedy disappearance and frequent recurrence. Conjugate deviations and ophthalmoplegia externa are caused almost exclusively by syphilis."

"A unilateral iridocycloplegia may remain the one symptom of syphilis of the nervous system for years." (See also *Pathology of the pupil* in this section.)

"Hemikenesia," or hemianopic pupillary inaction. Jess (*Arch. f. Augen.*, 71, p. 66) states that according to his investigations the existence or non-existence of hemiopic pupillary reaction or "hemikenesia" (as Hess has named the phenomenon), has been proven by the apparatus of Hess, which eliminates diascleral light, to be a reliable diagnostic aid in the localization of cerebral affections. The

opinions as to the value of hemikenesia have been divided because of the faulty technic employed by some in eliciting the test. Jess examined eight cases of hemianopsia with the refined and reliable method exploited by Hess, both as regards hemikenesia and the adjusting movements as described by Wilbrand, and was much gratified with the exact value of the Wernicke reaction test by the newer methods he employed. Three of the cases were definitely proven at the autopsy to have been correctly diagnosed as to the location of the lesion. One had a sagittal division of the chiasm causing bi-temporal hemianopsia. In each of these cases the inaction of the pupil to illumination of the blind half of the retina was positively demonstrated. The third case was that of a tumor of one occipital lobe with hemianopsia. In this case normal pupil response was elicited because the pupillary light reflex arc was unaffected. Other cases gave definite reactions or non-reaction of the pupil and were followed up to the post mortem table and found to be rightly diagnosed. (See *Wernicke's test* in this section.)

Hemiopic pupil reaction. Hesse (*Klin. Monats. f. Augen.*, Jan., 1909) as reported by Ballantyne (*Oph. Review,* Mar., 1909) makes an important contribution to the subject of the hemiopic pupil phenomenon. A good deal of controversy has centered around this symptom and it is noteworthy that Heddäus, who before Wernicke indicated the possibility of its occurrence, was one of the first also to deny the value of the test as reported elsewhere in this section (see *Wernicke's test*). Those who believe it to be unreliable base their objection on two arguments: (1) that only stimulation of the central part of the retina (macular region) can excite pupillary contraction and that the test is therefore theoretically impossible, and (2) that it is practically impossible to stimulate an isolated portion of the retina without at the same time stimulating other parts by diffused or diascleral light.

It is obvious that the reflection of light from the ophthalmoscopic mirror, alternately from one retinal side to the other, is open to the second of these objections and Hesse points out that other more carefully devised methods of making the test fail to overcome this difficulty.

The most recent and most careful experiments on the subject are those of Hess (see *Pupillomotor area of the retina* herein) who concludes that the pupillary reflex can only be excited by illumination of an area with a radius of 3 to 4 mm. at the centre of the retina.

Hesse's first object was to repeat the experiments of Hess and this he did without being able in any way to offset his results. Several further series of experiments on somewhat different lines, also confirmed Hess's view that the pupillary reflex could not be excited by illumination of the periphery of the retina. He finally succeeded, however, in demonstrating that the pupil reflex could be so elicited by the use of a specially devised method. This consisted in an ingenious adaptation of the photographic apparatus of Prof. Dimmer, in whose laboratory his experiments were carried out.

All previous results were fallacious in that they failed to prevent the excitation of the sensitive macula by a certain amount of diffuse light. He succeeded in eliciting a pupillary contraction by light stimulus applied to the retina as far as 45° or 50° from the macula, but the powerful illumination required, and no doubt the technical difficulty also, render the test of no practical value.

He concludes, therefore, that while he has succeeded in demonstrating the reflex excitability of the retinal periphery and while the hemiopic pupil phenomenon is theoretically possible, the latter cannot be put to any practical use. On account of the fallacies which attached to earlier methods of carrying out the test, the results hitherto reported are of no value.

The paper also embraces notes on the estimates of the minimum effective light stimulus and on the question of the "receiving organ" for the pupil reflex, which, with Hess, Hesse believes to be the outer segments of the cones. (See also *Wernicke's test.*)

Hemianopic pupillary reaction (Knies') without hemianopsia. Knies (*Text-book*, Am. Ed., p. 55) states that if the fibers of the optic tract which pass to the nucleus of the sphincter pupillæ are alone destroyed on one side and the anterior corpus quadrigeminum likewise, a peculiar symptom would develop, viz., hemianopic pupillary reaction without hemianopsia. This could only occur as the result of a lesion in the narrow space between the termination of the optic tract and the nucleus of the sphincter pupillæ. According to Wendel, the same thing could happen if one ganglion habenulæ were destroyed. This test should be applied in cases of suspected disease in the region of the primary optic ganglia. Knies reports a case in which the test was positive and the clinical signs of disease were harmonious with the theory that a lesion existed in the terminal ganglion of the cortical fibers of the optic tract in the external geniculate body.

Knies further states (p. 113) that no case of pure hemianopic pupil reaction with retained normal fields of vision was ever reported although it is probable that the condition is not very rare. The reason it is not discovered is that it produces no subjective symptoms and is not searched for. (See *Wernicke's pupil reflex* in this section.)

Hemiplegia, Inequality of the pupils in cerebral. Klipel and Weil (*Wien. Klin. Woch.*, January 10, 1913) state in about forty per cent. of the cases of cerebral hemiplegia there is a difference in the size of the pupils. This difference is noted when coma sets in. In the comatose state the wider pupil is on the side of the cerebral lesion, which is on the side opposite to the hemiplegia. In cases of hemiplegia without coma the dilated pupil is on the hemiplegic side, or on the opposite side to the cerebral lesion. Exceptions to this rule are noted, however, due to the fact that strong irritation of the cortex of the brain produces a dilatation of the pupil, while a weak irritation may produce contraction. Generally speaking, in all cases of coma, sleep, narcosis and intoxication the pupils are contracted. In the comatose state the pupillary difference in cerebral hemiplegia is brought about by this contraction of one pupil. Without coma the difference is brought about by dilatation of the same pupil. In the former case the contraction is produced by the natural effect of sleep on the unaffected hemisphere of the brain. In the latter case the pupillary difference is produced by cortical excitation of the unaffected hemisphere. Pupillary difference in coma indicates an organic lesion and excludes hysteria. Contraction or dilatation of the pupil on the paralyzed side is important from a prognostic standpoint as it indicates whether or not the affected hemisphere has the ability to respond to normal stimuli.

We may accept it as a general rule that the dilated pupil is usually on the side of the hemorrhage and may be the result of paralysis of the motoroculi, irritation of the sympathetic, or both.

Herpes iridis. This rare disease has been studied by Bellwinkel (*Inaug. Dissert.*, Munich, 1913). He collected the histories of nine cases. Herpetic vesicles appear on the pupillary border of the iris associated with hemorrhages in the anterior chamber and usually herpetiform keratitis. Pain is a prominent symptom. The complications noted are profound synechia with occlusion of the pupil. Other complications are glaucoma, optic neuritis, macula cornea, anesthesia of the cornea, etc. The iris presents an appearance somewhat similar to that of syphilitic condylomata.

Herpes zoster ophthalmicus. In this condition paralysis of the sphincter pupillæ is not uncommon, the pupil being widely dilated and fixed. This is by no means the invariable rule. Slightly dilated and sluggish pupil is more common, being due to paralysis of the sensory nerves of the iris.

Wallace (*Ophth. Record,* Vol. XX, No. 3) noted moderate dilatation and irregularity of the pupil of the affected eye with no response to light. This was associated with paralysis of the other branches of the third nerve. In a typical case recently observed by the present writer the third nerve was not involved, but there was paralysis of the fourth nerve. The pupil was slightly dilated and reacted feebly to the light.

Heterochromia iridum. The iris sometimes changes color as the consequence of uveitis and other intraocular diseases, e. g., iritis, glaucoma, etc. In the case where the natural color of the iris is brown, the affected iris will sometimes turn to a blue-gray, the difference in coloration becoming striking. The pupil in such cases may remain black, but sometimes in the changing eye it turns gray. This grayness of the pupil is usually due to a cataract formation, for cataract is not an unusual sequel to chronic uveitis. In other cases punctate deposits on the inner surface of the cornea cause a dull or lusterless appearance of the pupil.

Williams, of Philadelphia (*Ophth. Record,* July 1913, Vol. XXII, No. 7), reports a case of acquired heterochromia and gives interesting data showing the observation of others in this connection. The present writer has seen it many times. Very often the affected eye presents only a slight change of color and in some of these no evidence of punctate keratitis or cataract can be observed.

Heterochromia iridum is frequently a congenital or physiological peculiarity and in these cases the pupils appear quite normal to every test.

Hippus, Classification of. Breuil (*l'Ophtal. Province,* Vol. III, p. 186, and *Archiv. d'Ophtal.,* Feb., 1906) gives the following classification of hippus: (1) Hippus from hyperexcitability of the nervous centers and "reflex hippus" as from otitis (case illustrating the latter is given). (2) Hippus in connection with the respiratory act and also with circulatory disturbances in which there is mechanical irritation of the sympathetic. (3) Hippus in paralysis which is undergoing a cure. (4) Rhythmic hippus as seen in occasional cases of hysteria, etc. (See *General considerations* at the beginning of this section.)

Holocain, The value of the negative action of. Holocain in one per cent. solution occupies a unique and valuable position in ophthalmic practice because of (a) its deep anesthetic properties on the cornea and iris when dropped in the eye and (b) because it has no effect on the pupil.

The positive effect of mydriatics on intraocular tension is referred to in this article elsewhere and there are instances such as when desiring to take the tension with the tonometer that it is necessary to secure profound anesthesia with no dilatation of the pupil. Holocain is our only anesthetic that will accomplish this.

Since the dilatation of the pupil is always annoying to the patient holocain is of much value as an anesthetic in the treatment of conjunctivitis to counteract the pain produced by metallic astringents and because of the fact that the pupil and accommodation are unaffected by its use. Its anesthetic power is quite equal to that of cocain and its action is as lasting. It is slightly more irritating but this effect is very brief and is easily borne by the patient. It is distinctly antiseptic, a property cocain does not possess.

Homatropine dilatation. Duane (*Arch. of Ophthal.,* Vol. XXXVIII, No. 5, p. 512) reports results of experiments in over five hundred refraction cases where homatropin was used. With the delicate test described by Uhthoff, he found that after the instillation of the drug it took about twenty-five minutes for the light reaction to be completely abolished. In some cases, however, it disappeared in less than twenty minutes and in others it persisted for from forty minutes to an hour. The duration of complete immobility lasted longer in young subjects, while in those older it was relatively shorter as the age increased.

The pupil begins to dilate under the influence of homatropin in from twelve to fifteen minutes and then dilates quite rapidly. The addition of cocain to the homatropin solution enhances the rapidity and extent of dilatation of the pupil but not the amount of cycloplegia. The combined solution seemed to have a sharper and more evanescent action on the left pupil than on the right. There is no constant relation between the mydriatic and the cycloplegic action of the drug. The pupil may dilate ad maximum and the accommodation may still be active to a certain extent.

Homatropine, Persistent mydriasis after the use of. Wilder (*Ophthal. Record,* August, 1901, p. 438) reports the case of an iron-moulder of twenty-seven who had sustained an injury to his head. A clot of blood was removed from beneath the parietal bone. This operation cured him completely of headaches. Then homatropin was instilled for the purpose of determining the status of his refraction, which was found to be nearly normal. Ten months after he returned stating his right pupil never recovered from the effect of the drug, but that his left pupil had promptly recovered and was normal. Examination revealed the right pupil to be 6 mm. in diameter and immobile to light and convergence.

In the discussion Pinckard reported that he had observed persistent mydriasis after homatropin was instilled in a girl's eyes. The mydriasis and cycloplegia were complete after ten months. He ascribed the condition to hysteria. Casey Wood stated he had found several similar cases reported in the literature and that it was possible there was in these cases an organic poison from the drug elaborated in the system.

Horner's syndrome. Sicard and Galezowski (*Rec. d'Oph.*, XXXII, p. 225) saw six examples of Horner's syndrome (miosis, ptosis, enophthalmos, etc.) among a large number of cases where the Gasserian ganglion had been injected with alcohol and carbolized glycerine for the relief of trifacial neuralgia. The symptom persisted from a year to eighteen months.

Dufour (*idem.*, XXXIII, p. 90) saw the same symptom due to the pressure of a goiter on the right sympathetic, and Sébileau and Lemaitre (*ibid.*, p. 43) have several times observed the coexistenee of Horner's with Jackson's syndrome (hemiplegia of the vocal cord, palate, tongue, sterno-mastoid and trapezius muscles).

When Horner's syndrome was present the pupil of the affected eye would promptly dilate when 1-1000 solution adrenalin was instilled, but the unaffected fellow eye would not be influenced one way or the other with the solution. This reaction, which is also mentioned in discussing glycosuria (see elsewhere in this section) is specific for miosis from paralysis of the sympathetic. See *Ganglionectomy,* also *Mydriatics-combined* in this section.)

Hutchinson's pupil. Monocular dilatation of the pupil.

Hyaline degeneration of the pupil margin. Axenfeld (*Bericht der. Ophthalm. Gesell.,* Vol. XXXVII, 1912) observed that the pupils often dilate imperfectly even where there has been no previous disease of the iris. He was lead to study why it was that in some eyes the action of the mydriatic was to produce widely dilated pupils, while the same in other eyes produced only slight dilatation. Among the latter, he found more examples among elderly people. He explains some of these cases, at least, by the presence of hyaline degeneration of the pupillary margin of the iris.

Fuchs, Meller and Seefelder have also noticed the same condition. There is in these cases a more or less sharply defined opalescent or grayish-white ring in the substance of the tissue at the pupil margin. This ring is often not complete. It is detected quite frequently among the senile cataract cases. Attention is called to the fact that pigment atrophy or depigmentation of the posterior surface of the iris produces an appearance very similar to hyaline degeneration.

Leber in discussing this subject, said that in many of these cases the rigidity of the pupil was not due to atrophy of the musculature but to a thin layer of adventitious connective tissue which covered the iris and which by its inherent contraction caused eversion of the uveal layer at the margin of the pupil and ectropion of the sphincter pupillæ, but Axenfeld in reply stated that the appearance noticed by Leber was only present in eyes which were essentially pathological.

Lauber, at a meeting of the Ophthalmological Society of Vienna, 1910, reported the case of a man aged 72 having cataract in which the pupillary margin appeared gray. No retinal pigment could be demonstrated with a magnifying lens. Moreover trans-illumination demonstrated that the pupil seemed much larger than it really was because the pupillary margin was free from pigment thus permitting the passage of light. There was rigidity of the iris noted. Mydriatics did not dilate the pupil. Everything seemed to indicate that there was hyaline degeneration as described by Fuchs.

Hypophysis, Tumor of the. Shoemaker (Knapp's *Archiv.*, March, 1910, XXXIX, No. 2, p. 132) reports a case of hypophyseal tumor which was diagnosed *in vivo* and corroborated *post mortem* in which during the course of the disease there was complete loss of the temple fields of vision in both eyes. The pupils in this case were equal in size (3 mm.) and normal in reaction to light, convergence and accommodation. In the cases which the present writer has seen the pupils behaved differently so that there were no uniform pupil findings. Unequal pupils were the rule, the more affected eye presenting the larger pupil. There was sluggish response present till blindness set in, and in one case the pupil responded slightly to light when blindness was total.

Hysterical seizures. The pupils during hysterical seizures usually react to the light perfectly. The present writer recalls a case where a patient assumed an epileptic seizure in which he was able to diagnose hysteria by the prompt reaction of the pupil to light. In epilepsy the pupils during the attack are widely dilated.

Redlich (*Deutsch. Med. Wochen.*, 1908, p. 313) noticed hysterical pupillary paralysis. The subject, a woman of thirty-nine, exhibited dilated and immobile pupils when making violent muscular efforts or crying out in the hysterical attacks. The dilatation and fixity of the pupils were similar to that seen in epilepsy. But if the patient employed convergence the pupils during the attack would invariably contract. From this he deducts that the dilatation in hysterical storms is due to stimulation of the sympathetic.

Carline (*La Clin. Oculistica,* September, 1905) observed transitory dilatation of the pupil in a case of hysteria. The pupil would dilate ad maximum and would remain so for a few hours or sometimes for four or five days. The dilatation of the pupil was observed in one eye only, the other being normal. He concludes that the dilatation was due to stimulation of the sympathetic of the affected side.

G. E. deSchweinitz (*Ophthal. Rec.*, Nov., 1905, p. 554) states that at one time neurologists maintained that the differential diagnosis between epileptic and hysteric seizures could be made by observing the pupils, which in the case of epilepsy would be widely dilated and fixed, while during hysterical fits they would respond to light. The investigation of Karplus, however, shows that pupil immobility may occur during hysterical attacks and that it is a frequent phenomenon in paroxysmal hysteria depending in all likelihood upon a cortical origin, and that therefore the pupil signs alone are not sufficient to make a differential diagnosis between the two states.

Hysterical blindness. The pupils in this affection afford valuable information although there is no absolutely uniform behavior present. They may be contracted or dilated, usually they are normal and react to light, thus affording in many cases a positive clue to the real nature of the affection. deSchweinitz states (Posey and Spiller, p. 615) that complete blindness in the absence of ophthalmoscopic signs of optic nerve disease, associated with normal pupil reaction to light, would strongly suggest, if not prove, the presence of hysterical taint, but because in rare instances the pupils fail to react to light the absence of pupil reflex does not necessarily exclude hysteria.

In some forms of retrobulbar optic neuritis, or strangulation of both optic nerves from pressure on the nasal side of the optic foramina in acute posterior ethmoid or sphenoid disease the patient may be blind and present at first no ophthalmoscopic evidence to prove blindness, but the pupils will be dilated and fixed. This finding would tend to rule out hysteria which may otherwise be suspected. In case monocular blindness is present from acute posterior ethmoidal empyema the pupil is not dilated because of the consensual influence from the normal fellow eye.

The dilatation and fixity of the pupils in hysteria may, by clandestine observation, often be discovered to be due to intentional use of some mydriatic drug like atropin drops. In a case the writer once saw the monocular dilatation of the pupil was discovered to be due to the patient (a trained nurse) sticking pins in the superior cervical ganglion. (See *Mydriasis* in "General considerations," this section.)

Holden (*Arch. of Ophth.*, July, 1914, Vol. XLIII, No. 4) saw two cases of genuine hysteria in which total blindness was assumed and where the diagnosis was determined from the normal appearance of the fundus oculi and other features. The pupils were round, equal and slightly sluggish in reaction. After recovery the pupils responded promptly and fully.

Hysterical pupil phenomena. deSchweinitz (Posey and Spiller, p. 646) states that although pupillary anomalies are rarely found as permanent manifestations in ocular hysteria the following pupil conditions have been reported: (1) Contraction of the pupil, i. e., either spasmodic or paralytic. (2) Dilatation of the pupil, i. e., either spasmodic or paralytic. Two general classes of cases are observed (a) dilated pupils which respond to light even when blindness is claimed and (b) dilated pupils which do not respond to light. (3) Interchange of mydriasis and miosis. (4) Unilateral mydriasis in one class of cases associated with paralysis of accommodation, in another class with retained accommodation. (5) Mydriasis with sluggish reaction to light and paralysis of accommodation. (6) Paradoxical pupil reaction.

These variant pupillary phenomena are, in true hysteria, to be attributed to spasm of the sphincter in cases of miosis and through psychic, cortical or sympathetic influence in the cases of mydriasis. The question of true paralytic dilatation of the pupil in a suspect can be cleared up by the use of eserin drops when it is found the pupil under their influence will readily contract, whereas if the pupil is dilated from the secret use of a mydriatic drug no such contraction will occur when the eserin drops are instilled.

Hysterical ptosis. Wilbrand (*Arch. of Ophth.*, Nov. 1904, p. 638) found the pupils much contracted and reacting slowly to the light in a case presenting hysterical ptosis.

Immobility, (reflex). The relation between lesions of the cervical spinal cord and reflex immobility of the pupil which has been commonly accepted, is denied by Bumke (*Klin. Monatsbl. f. Augenheilk.*, Vol. XLV, p. 257). He argues that Bach's experiments contradict the dependence of light rigidity upon changes in the cervical spinal cord because the complete severance of the spinal cord from the afterbrain did not influence the movements of the pupils. He further states that there is no proof that the immobility of the pupil is not caused by a disturbance of the reflex arc between the primary optic center and the third nerve nucleus.

Fuchs (*Wien. klin. Wochensch.*, No. 14) states that the assumption that reflex immobility of the pupils is characteristic of tabes and that absolute immobility is, on the contrary, diagnostic of cerebral syphilis is not strictly correct, because in each disease both sorts of pupillary disturbances are met with.

Indirect or consensual light reflex test. The patient stands in front of a window with the daylight streaming equally in both eyes. He is instructed to direct his gaze and attention at an object located at infinity in order to eliminate the influence of convergence and accommodation on the pupil. The observer screens both eyes with the palms of his hands which should not be clammy or cold (to avoid the sensory reaction) the eye under observation is only partly covered with the hand so that the observer may see the pupil by peeping under it. The *other* pupil is now alternately exposed to light and darkness while the observer watches the pupil which is kept partly screened. The normal effect of the sudden entrance of daylight in the unobserved eye is to produce contraction of both pupils even when the observed eye is still shuttered.

The test may also be conducted successfully in a darkened room. Weeks (Posey and Spiller, p. 301) states, "The indirect reaction may be excited by reflecting light into the one eye by means of a mirror from a source of light behind the plane of the patient's face."

Inequality of the pupils, Clinical value of. Schaumann (*Finska Läwäretallsk Handl.,* March, 1903) states that inequality of the pupils is much more frequent with persons of internal disorders than in healthy persons, the percentage being 18 to 46 in the former, and 1 to 10 in the latter. He examined 1,186 out-door patients and 727 hospital patients with reference to this sign. Of the former, 27.9 per cent. had inequality of the pupils, and of the latter, 37.8 per cent. He therefore concludes that simple inequality of the pupils is a constitutional peculiarity to the class with the somatic stigmata of degeneration, and that it has little diagnostic importance. Of the total number of his patients there were nine who did not show good response to light and among these cases organic disease was found.

Simple inequality of the pupils with retained reaction should be regarded as a physiological peculiarity for it is quite common among normal people.

Reber (*Ophthal. Rec.,* December, 1911, p. 750) examined one hundred recruits for the U. S. Army as regards inequality of the pupils in normal persons and decided from this study that such inequality is very small, indeed so small as to be negligible.

Inequality of the pupils and inequality of refraction, Relation between. Frenkel (*Annales d'Ocultistique,* October, 1906, reviewed by Beard of Chicago, *Ophthal. Rec.,* January, 1907, p. 28) being unwilling to accept as a fact every statement that is made by his colleagues in ophthalmology, has made some investigations in the matter of anisocoria in anisometropia. He states that there was no mention of anisocoria in anisometropia more than fifty years ago. He divides into two camps the authors who have expressed themselves as to the question, viz., those who affirm such a relation and those who deny it. The latter are relatively few; on the other hand, the belief in a physiologic anisocoria in conjunction with and dependent upon anisometropia he finds quite prevalent. The larger pupil, it is usually asserted, pertains to the side that has the greater refraction error.

For five years Frenkel examined his refraction cases carefully for differences in the pupillary diameters. He gives in three tables the results of his clinical observations. The first table shows twenty-five instances of inequality of refraction without inequality of the pupils; the second shows ten inequality of the pupils without unequal refraction and the third shows ten instances of unequal pupils and unequal refraction. All cases of inequality of pupils and inequality of refraction in which there were other reasons for the anisocoria were omitted. In other words, only the so-called physiologic inequality was considered. Frenkel does not admit that a difference in the visual acuity, as from corneal opacities, cuts any figure in pupillary inequality. In summing up, then, Frenkel found in about 5,000 cases only ten in which anisocoria and anisometropia were associated (0.2 per cent). Of these ten cases, six of them had the larger pupil on the side of the greater ametropia and four on that of the lesser. The larger pupil corresponded to the higher refraction (i. e., more myopic or less hyperopic) in five cases. His conclusions are that nothing justifies the assertion that certain cases of pupillary inequality depend upon an inequality of the refraction. Nor that the larger pupil corresponds more often to the side of the greater ametropia, nor that it corresponds, with any greater frequency, to the side of greater refraction. And, finally, that there is no scientific reason for admitting any sort of relation between anisocoria and anisometropia. (See *Anisocoria*, this section, also *Nasal influence.*)

Infants' pupils. Bartels (*Zeit. f. Augenh.*, XII 6, p. 638) found the average diameter of the pupil in infants, after adaptation to light, to be between 2.5 and 3.25 mm. During sleep the pupils of infants are markedly contracted (1.5 mm.). There was no difference noted in the sexes. The normal dilatation of the pupils in infants never exceeded 5 mm. but atropin drops caused a prompt dilatation of 5.5 mm. (See also *Newly born, Pupils in.*)

Inhibitory fibers connecting the centers of pupillary dilatation and contraction. Weeks (Posey and Spiller, p. 297) states that the fibers which innervate the dilator pupillæ have their origin in the ciliospinal center of the spinal cord, situated in the anterior cornua in the lower part of the cervical and upper part of the dorsal cord. According to Bach, this center is connected with the sphincter nucleus of the third nerve.

Bach also states there is a center located in the medulla which is inhibitory to both the ciliospinal center and the sphincter nucleus. This was corroborated by Ruge, who found that after complete division of the medulla oblongata in rabbits, perceptible pupillary reaction could be obtained. Parsons (*Jour. Physiol.,* XXVI, p. 366) proved that if the sympathetic be divided dilatation of the pupil can be obtained by stimulation of the brain cortex. These tests seem to prove there is an inhibitory influence in the brain on the sphincter nucleus which permits dilation of the pupil independent of the action of the sympathetic. (See Bach and Meyers hypothetical pupillary centers.)

Innervation of the pupil. Parsons (*Royal Lon. Ophthal. Hosp. Rep.,* Vol. XVI, p. 1) experimenting on cats, dogs and monkeys, found that there was distinct dilatation of the pupils on stimulating the cerebral cortex after section of the cervical sympathetic nerve, but after dividing the oculomotor nerve intracranially and stimulating the cortex, this dilatation did not occur. He argues from this that the cortex exerts an inhibitory influence on the third nerve and furthermore, that there is an association between the action of the third nerve and the cortex, independent of the cervical sympathetic.

Tschirkowsky (*Neurolog. Westn.,* Vol. XI, No. 4) demonstrated that after division of the optic nerve the pupil further dilated only when tactile stimulus was applied. If, however, the cervical sympathetic was divided or the ganglion was extirpated the pupil no longer dilated to sensory stimulation.

These observations of Parsons and Tschirkowsky studied together seem to prove that dilatation of the pupil may be brought about through two independent pathways, (1) through cortical impulse acting to inhibit the contraction of the sphincter pupillæ along the route of the third nerve, and (2) through the well-known action of the cervical sympathetic.

Dubois and Costelaine (1907) (*Archiv. d'ophtalm.,* XXVIII, p. 310) conducted experiments similar to those of Parsons, on dogs, and found that after section of the cervical sympathetic and oculomotorius there was entire absence of pupillary dilatation from stimulation of the sensory nerves or the cerebral cortex.

Isolated from innervation. Hesse (*Klin. Monatsbl. f. Augenh.,* Feb., 1912) described a case in which, owing to the complete resection of the optic nerve, including the ciliary nerves and ganglion, all the pathways of innervation to the iris were severed during a Kroenlein operation performed for the removal of a tumor-mass that occupied the orbit. The observations on the pupil were made three and four years after the operation. The pupil in this eye three years after the operation was contracted to a diameter of two mm. and did not dilate in darkness or further contract in the light, either directly or consensually, but it did dilate with atropin and it further contracted with eserin. This is interesting as going to prove the existence of intra-ocular ganglionic structures from which final neurons arise, for Hesse maintains there was no connection left between the iris and any of the pathways of nerves supplying it. Six months later the pupil in this eye was found to be dilated to 6 mm. in diameter and was oval horizontally. At this time the iris stroma was seen to be atrophic. From this case Hesse argues that miosis is the true position of rest. The dilatation noticed later was the result of atrophy of the iris musclature.

Ballantyne (*Ophthalmoscope,* Aug., 1915, p. 406) discussing the case argues that the iris could not retain its muscular tone for four years after complete severance of all the nerves leading to it and states, "One must assume that the last neuron could not have been divided."

The case is unique and it is hoped other cases of like nature will be found and carefully analyzed and reported. It is well known that normal nerves when resected will in the course of rather a short time reunite and functionate. In evidence of this, witness the return of sciatica after resection of the great sciatic nerve. The writer once removed six inches of the supraorbital nerve for the relief of supraorbital neuralgia and the nerve trunk grew back again in the course of a few months. It is quite possible that the cut nerves in Hesse's case grew again and that innervation from their sources were to a certain extent re-established.

Pollock and Ingles (*British Med. Jour.,* Nov., 1913) experimenting on albino rabbits found that denervation of the iris by removing the ciliary and cervical sympathetic ganglion did not completely destroy pupillary reactions. They concluded that a motor plexus with nerve cells exists independently in the sphincter and dilator pupillæ muscles. The plexus persists after complete separation of the iris from the central nervous system. (See *Mechanism of pupillary movements.*)

Inspiration, Mydriasis synchronic with. Wiesener, of Berlin, reported the case of a woman of 60 who had paralysis agitans and also paralysis of the cervical sympathetic as expressed in ptosis, enophthalmos, hyperidrosis and miosis. The pupils were elliptical (cat-like) and every time she inhaled deeply they would dilate. DeRoch, of Geneva, had observed a similar case. Wiesener has observed slight dilatation of the pupils in normal individuals on taking deep and prolonged inspiration and states he has demonstrated this with his own pupils.

Insanity. De Montzel has noticed a difference as to the presence of abnormal pupils among the acutely insane and the old hopeless cases. In the former, among twenty cases, the pupils were normal in 50 per cent. In the latter, among fifty-seven cases the pupils were normal in only 5.2 per cent.

Regarding the percentages of abnormalities of various kinds, among the chronically insane, as studied by De Montzel, the following table taken from Posey and Spiller (*The Eye and Nervous System*, p. 510), will show the variations:

Inequality, 45.6 per cent.; miosis, 17.5 per cent.; mydriasis, 21 per cent.; deformities, 43.8 per cent.; abnormal light reflex, 56.1 per cent.; abnormal accommodation reflex, 35 per cent.; bilateral identical alteration, 26.3 per cent.; Argyll-Robertson pupil, 33.3 per cent.; inverse sign, 10.5 per cent.; paradoxical reaction, 1.7 per cent.; hippus, 3.5 per cent.

From the above table we note that there are no diagnostic pupillary abnormalities peculiar to any form of mental derangement. There is a wide range of misbehaviors on the part of the pupils in insanities and the same case may present variations in the progress of the disease. During the maniacal storm the pupils are often dilated; this may be explained by the effect of cortical excitability on the sympathetic nerves supplying the dilator pupillæ, but often the pupils are found to be contracted, especially in tabes with psychoses and in paresis and cerebral syphilis. The findings of Mignot in one hundred and forty-four insane subjects may be taken as a proportionate index (paresis excluded). He found inequality in 39 per cent.; disturbed light reflex in 43 per cent.; disturbed accommodation in 69 per cent., deformities of the pupil in 35 per cent., miosis in 17 per cent. and mydriasis in 35 per cent.

Wilbrand (*Wien. klin. Rund.*, 1906) found the pupils in progressive paralysis of the insane characterized at times by marked variability from day to day or hour to hour, while again there would be uniform behavior for local periods. He does not offer an explanation for this bizarre behavior of the pupil.

Baatz was unable to find any characteristic pupil phenomenon among the insane excepting in dementia paralytica. Among these cases he usually found dilated pupils.

Irideremia, Essential. deSchweinitz (*Trans. Am. Ophthal. Soc.,* 1915) reports the case of a woman aged twenty-three whose left iris changed color and gradually resorbed so that after three years there was no vestige of normal iris tissue. The fellow eye remained normal. The affected eye was normal in every other respect. (For full report of this case see Vol. IX, pp. 6629-6631, this *Encyclopedia.* Also for essential atrophy of the iris see Casey A. Wood's case under *Atrophy of the iris* in this section.)

Iridodonesis, The pupils in. While there is a tremulousness of the iris present, the pupil itself does not change its size during the tremulous act. The plane of the pupil may, however, be tilted because of the lack of support of the iris incident to the dislocation of the lens present. The pupil is often though not always somewhat dilated and reacts less than normally to light stimulus.

Iridodialysis. The pupil is usually slightly flattened on the side where the iris is torn from its attachment. The pupil responds to the light in cases where the sphincter pupillæ is not paralyzed. The red reflex can be seen through the dialyzed part and if a card be held in front of the central pupil the patient can fix through the artificial opening. It is usually impossible to secure a reattachment of the iris when it is torn loose at the periphery although cases of spontaneous as well as surgical reattachment have been reported. Molesworth reported the case of a man struck on the right eye with a piece of wood. There resulted a cleft in the root of the iris on the temple side. The function of this section of the iris recovered after atropin and bandage for ten days and healing took place without any cleft being visible afterwards. This case sets to naught most of the recent declarations made by Henderson, Fuchs and others that the cut or torn normal iris never heals with a scar. Molesworth's case would seem to argue that the dilatation of the pupil with atropin had permitted the torn ends of the iris fibers to approximate and heal. If this is true the case is unique.

Iridoplegia, Hysterical. Frank (*Arch. of Oph.,* May, 1904, Vol. XXXIII, No. 4) described the case of a woman of 32, who presented unequal pupils, the left measuring 5 mm., the right 3 mm. and he stated that the left pupil dilated when the patient became nervous and excited and that this dilatation was accompanied by dimness of vision. The right pupil responded normally to light, the left did not respond. Hysteria was diagnosed because of the typical fields of vision and the absence of organic disease, as was proven by the after course of the case. (See *Hysteria* in this section.)

Iritis, The size of the pupil in. Herbert (*Ophthalmoscope,* Sept.,

1904) states that his experience in India, regarding the size of the pupil in iritis, is at variance with the usual text-book descriptions. Grouping together primary iritis and iridocyclitis and secondary involvements from severe corneal affections, quite half the cases in Bombay, presumably untreated by mydriatics, show a slight enlargement of the pupil, as compared with that of the unaffected fellow eye, on distant fixation in ordinary daylight. In mild and especially early inflammation, likewise in the hyperemia which accompanies slight corneal lesions, the pupil is usually contracted; and this contraction is at first largely the result of spasm of the sphincter. The small size may persist in later stages with a high grade of inflammation, owing to the anchoring of the pupil by posterior synechiæ, and a pin-point contraction may finally result from a shrinkage of the pupillary membrane. Chiefly in severe attacks, but also in some quite mild inflammations, especially such as have lasted for a few weeks, paresis of the sphincter may be responsible for a slight enlargement of the pupil. Plus tension, where present, must tend also to dilate the pupil, but the enlargement still remains only very slight. Congestion and infiltration of the iris insure this. An earlier contracted state of the pupil is not infrequently outlined in these cases by a ring of pigment deposited on the lens-capsule. That the dilatation of the pupil is not an effect of previous mydriatic treatment may be inferred—quite apart from the patient's statements—from the uniformly low degree of the alternation in size, from the absence of marked irregularity in outline of the pupil and often from the prompt response to the instillation of atropin at the hospital. In India the effects of severe iritis are much more frequently seen than in England. This is largely owing to the cases often remaining for long practically untreated, or to the eyes being simply irritated by native quack treatment.

That the pupil is contracted in iritis is a well known fact. It is a rational inference that the congestion of the iris vessels will contract the pupil mechanically if for no other reason, but occasionally we meet with cases of plastic irido-cyclitis in which the pupil appears half dilated.

The cause of the dilatation of the pupil in the presence of engorged blood vessels of the iris must be explained by the influence of obtundity of the nerves of the iris from raised intra-ocular tension aided by the withdrawal of light stimulus to the retina from the cloudy media.

Iritis, Quiet. Occasionally we meet with a case of iritis in which there are none of the classical symptoms present. The main symptoms are impaired vision, photophobia and lachrymation. The pupil may become adherent to the lens capsule throughout. It then becomes slightly contracted and iris bombé may occur. A case of this nature was reported by Orendorff before the Colo. Ophth. Society, January 18, 1913. The patient, a girl 18 years of age, had no known constitutional taint other than muscular rheumatism. In the discussion Coover refers to the likelihood of recurrent attacks and advises a broad iridectomy.

Aufmwasser thought the nose was to blame for the condition.

Jumping mydriasis. Miloslavich (*Wien. Klin. Rund.*, January 7, 1911) defines jumping mydriasis to be a dilatation of one pupil at one time and the other pupil at another time. This jumping of the dilatation from one pupil to the other may occur in some cases within an hour's time; in other cases a day's interval of time may elapse.

The literature shows that jumping difference in the pupils occurs in tabes, myelitis and in other organic affections of the central nervous system. It has also been observed in neurasthenia and hysteria. (See *Changing pupil* in this section.)

Jumping pupil, Monocular. Bielschowsky (*Klin. Monatsbl. f. Augenheilk.*, Vol. XVI, p. 308) describes a peculiar form of jumping pupil. The patient, a woman of 20, had had right third nerve paralysis since childhood. In this eye there were alternating phases of mydriasis and miosis at intervals of 20 to 30 seconds. The miosis was associated with a downwards rotation in response to the effort of convergence. The other eye presented no pupil abnormalities. He explained the case by assuming that the third nerve palsy was not complete and that excitation of the nucleus induced by efforts of convergence was accompanied by an overflow of stimulus to the center for pupillary contraction. (See *Cyclic contraction and dilatation* in this section.)

Knies' sign. Knies' sign is, "When hemianopic pupillary inaction exists without concomitant hemianopic visual defect," and it indicates that the lesion is between the nucleus of the third nerve and the optic tract (Lewis: *Jour. Ophth. and Oto-Lar.*, Feb., 1908). (See also *Hemianopic pupillary reaction* in this section.)

Landry's paralysis. Acute ascending paralysis first described by Landry in 1859, is characterized by loss of function of the lower extremities gradually passing upward and in some cases ending in death in a few days. Since the pathology is in the lower part of the spinal cord at first and does not affect the upper part of the cord till near the terminal phase, the pupils do not show any symptoms. Irregular and contracted pupils have, however, been noticed shortly before death in a few cases.

Luminous intensity, Pupillary movements and. Ovio (*Annal. di ottolm.,* 1905, 102) demonstrated a relation between the diameter of the pupil and the intensity of light. From the classical researches of Lambert he deduces the law that the increase of the pupillary surface is inversely proportionate to the square root of the light strength. But he agrees that the pupillary variations are not uniform with uniform variations of the light; moreover, that there is greater reaction when the same light intensity falls directly on the macular region as compared with the reaction when the light falls on the periphery. The effect of convergence is to overcome the dilatation in a dull light so that the tests to be of value must be conducted in the relaxed eye.

Nagel (*Berlin Ophthal. Society, Trans.,* December 19, 1907), experimenting to determine the adaptability of persons with large pupils to darkness, found that they are at first at an advantage but later at a disadvantage. While the period of adaptation in them is somewhat diminished, they are more readily dazzled when returning to the light and exhibit the signs of exaggerated photophobia. (See *Adaptation, also Threshold value* in this section.)

Light reflex in the fetus, Early appearance of the. Magitot (*Annales d'oculist,* CXL, p. 161) demonstrated contraction of the pupil to light in a fetus five months old. This indicates the early development of the visual cells, the pupillomotor fibers of the retina, the oculomotor nucleus and the sphincter pupillæ. Since the optic nerve fibers have no medullary sheathes in a five months' old fetus, Flechsig's view that the latter are necessary to the conductivity of nerve fibers is incorrect.

Light reflex tests. As explained elsewhere in this section there are two light reflex pupil tests in common use: (1) The *direct* reaction, as when light and shadow are alternately made to enter the eye under observation. (2) The *indirect* or *consensual* reaction, as when light and shadow are alternately made to enter the fellow eye, the observed eye being in subdued unaltered light.

In normal persons the pupil under observation in these tests contracts and performs certain movements while under the influence of the contraction impulse and this, the normal pupillary contraction, is taken as a guide or standard of comparison in estimating abnormal pupillary behavior.

We speak therefore of the "direct reaction of the pupils," and the "consensual reaction of the pupils." Both of these reflexes are due to the integrity of the light reflex arc which we should understand to be anatomical structures designed for the transference of a stimulus incited by light entering the eye and comprising the so-called pupillary nerve-fibers in the retina, optic nerve and optic tract as well as certain pupillary centers in the brain (centripetal fibers) and return fibers beginning in the pupillary centers in the brain and traversing the third nerve to the ciliary ganglion behind the eyeball thence to the ganglia of the choroid and finally to the sphincter pupillæ (centrifugal fibers). The going impulse is called afferent, the return impulse efferent and the "arc" comprising the nerve fibers, nerve centers and the ganglia stations combined, is known as the "light reflex arc." (See *General considerations* introductory to this section, also *Mechanism of pupillary movements.*)

Malingering blindness. The contraction of the pupils to light does not prove that the patient who assumes blindness can see, although the pathological conditions permitting reaction of the pupils to light in genuine blindness are extremely rare.

Swanzy states a lesion of the visual centers in the cortex would produce absolute blindness and yet would permit pupillary reaction to light. The reliable test to prove assumed blindness is that of Priestley Smith and Edw. Jackson, which is to note the fusion of the visual axes after removal of a six degree prism held base out before one eye.

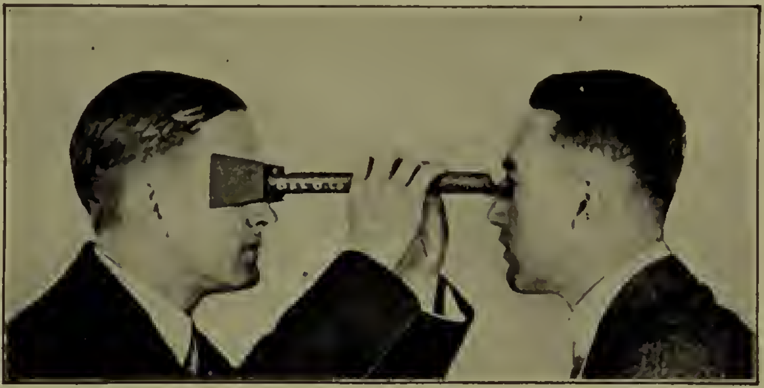
Measurement of interpupillary distance. Helmbold (*Zeit. f. Augenheilk.*, XVI, p. 45) describes his method of measuring the interpupillary distance, which consists in the use of his apparatus composed of two mirrors forming a right angle mounted on a crossbar having adjustable rests for the lower orbital margins and set in such a manner that the pupil of the left eye is observed by the right retina and *vice-versa*. Then an adjustable rod is so set that its image is seen to bisect both pupils. Double the distance of the rod from the line of intersection equals the exact interpupillary distance.

Duane (Knapp's *Archiv.*, XLIV, No. 5, p. 484) employs the German method of estimating the p. d. as follows: The patient's left eye and the observer's right eye are each covered. The patient then directs the visual axis of his uncovered eye in the pupil of the observer's open eye. A millimeter scale is held in front of the patient's uncovered eye in this position so that the zero mark on the scale is opposite the center of his pupil. Then without moving the scale he directs the patient to uncover his left eye and close his right, while he himself opens his own right eye and closes his left. The patient is now directed to look straight into the observer's right eye and when doing so the observer reads the scale noting the mm. mark that corresponds to the center of the patient's left pupil. This gives the exact mm. distance between the pupils when the patient's visual axes are parallel. It at the same time indicates the distance between the centers of rotation.

In this connection Bausch and Lomb, of Rochester, New York, have recently put on the market a gauge for measuring the interpupillary distance, as indicated in the accompanying illustration.

"This is a new ophthalmic instrument, designed to further the advance of modern refraction methods. It affords a reliable, convenient, and time-saving device for measuring the exact distance between the pupils. Its peculiar advantage is that it measures the distance of each pupil from the center of the bridge of the nose, a most important measurement for the accurate adjustment of a spectacle frame."

E. E. Maddox (*Ophthalmoscope,* June, 1907, p. 312) states the method most generally employed for taking the measurement of the interocular distance by means of a graduated rule is not entirely free from objection. The rule has to rest against the patient's face, either directly or indirectly. Moreover, the observer's eyes must be closed in turn. During the interval between their closure and the completion of the two measurements some lateral motion of one of the two heads is apt to take place.



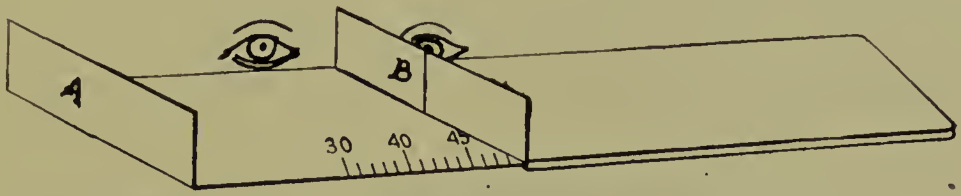
Interpupillary Distance Gauge of Bausch & Lomb.

Maddox devised his modified sextant to meet the requirements and at the same time overcome the objections met with by use of the ordinary millimeter scale. His instrument converts the angular motion of the sextant into rectilinear motion, enabling the instrument to effect its measurements irrespective of its distance from the two objects the separation of which it determines.

The sextant thus modified he calls a "duant." It is illustrated in the diagram. The distance between the mirrors is regulated by means of a screw.

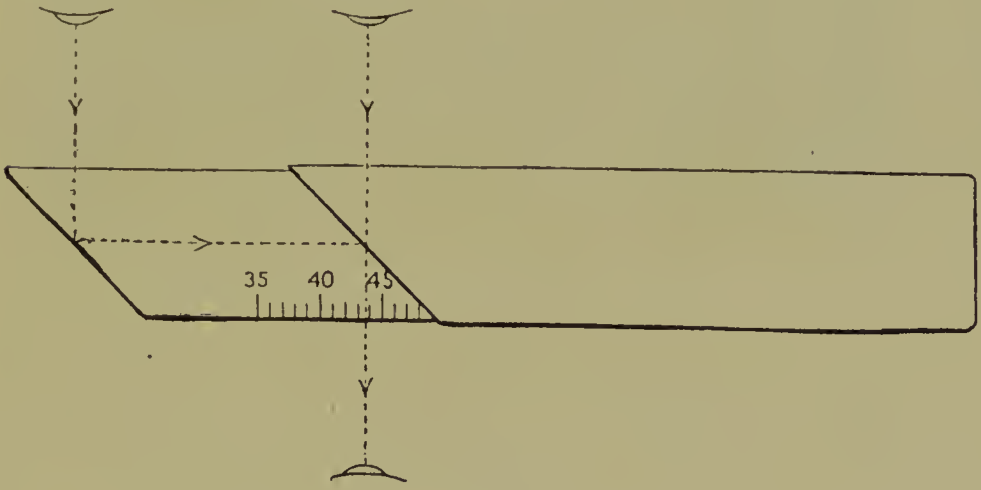
As shown in the figure, two narrow strips of metal, preferably of magnalium or aluminum, are held in a horizontal plane by one hand so that one readily glides over the other lengthwise and in close contact. The left extremity of each strip is turned upwards 90° in elevation, along a line which is 45° in plan, so as to support a mirror set at an angle of 45° to the length of each strip. The second shows these mirrors in plan. They are parallel to and facing each other, the left mirror having a greater vertical dimension than the right.

The instrument is held transversely by the observer between himself and the patient, so that the left eye of the latter is just visible



Maddox's "Duant" for Measuring Interpupillary Distance.

The arm A is higher than B. The mirrors face each other. A presents the back of the mirror as shown in the cut, and B presents the face of the mirror.



Illustrating the reflection paths in Maddox's "duant."

over the top of the right-hand mirror. The lower strip of metal is then slipped by the thumb screw until the patient's right eye is seen immediately below the left, after double reflection from the mirrors. If used as an interaximeter, the patient should direct his attention to some bright object, such as the illuminated test types or any distant source of light, above the observer's head, while the instrument brings one corneal reflection under the other.

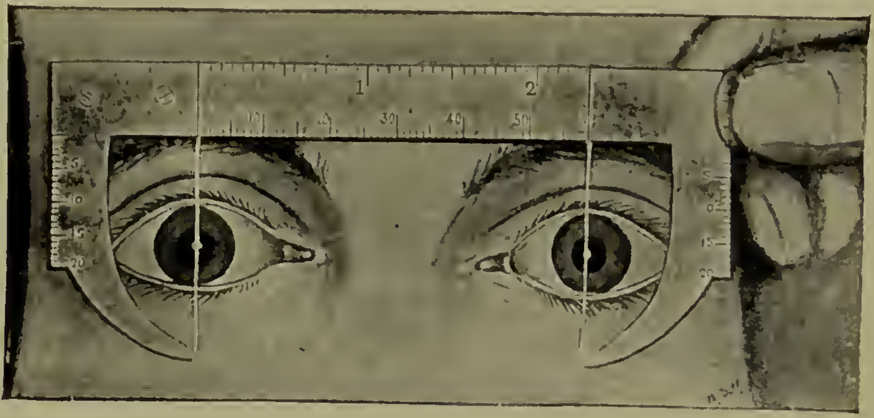
One precaution is essential to the use of the instrument: it should be held strictly at right angles to the observer's visual line. To secure this, each mirror is furnished with a spot or line in its centre.

When these two markings appear to coincide, the instrument is held truly.

The mirrors should not be allowed to lose their brightness, since double reflection implies a little loss of light, which becomes of consequence if they are not kept clean.

With a good instrument the interocular distance can be measured at a considerable distance from the patient—indeed, at some yards, in an appropriate light. It is needless to add that the position of the observer should not be such as to allow window light or luminous objects to be reflected into his own eye from the mirrors.

This being an instrument of precision, its accuracy should be tested before purchase, and it only remains to describe a simple way of doing so. Make two dots on a piece of paper, about 2½ inches apart and measure the distance between them with the instrument as close to the paper as possible. Thereupon make a second measurement at some distance from the paper. If the measurements agree with each other and with the actual distance between the dots, the instrument is accurate.



N. Bishop Harman's Ophthalmic Calipers.

Measurement of interpupillary distance by Harman's ophthalmic calipers. Harman, of London (*Ophthalmoscope*, Oct., 1911) has devised the instrument shown in accompanying illustration for measuring the "ocular base line" or interpupillary distance. Briefly the method of usage is as follows: The patient faces a distant point of light, either a window or lamp, and looks at it with both eyes. The surgeon faces the patient at arm's length and with his left eye sights the wire attached to the left arm of the calipers so that it passes through the exact center of the reflection of the light as seen on the cornea of the patient's right eye. The left arm of the calipers is now slid along the graduated bar till its wire as lighted with the surgeon's right eye passes through the exact center of the reflection of the light as seen on the cornea of the patient's left eye. It is manifest that the measurement as indicated on the fine scale marked on the base rod is the exact interpupillary measurement. The same method of testing will be found useful to determine the measurement when the patient is fixing on a near point as when the light is placed at the near point and the patient "fixes" on it.

Mechanism of pupillary movements. Angelucci (*Rev. gener. d'ophtal.*, 1900, Vol. X, p. 34) endeavored to explain the mechanism of pupillary reaction in accordance with the neuron theory. He contends that the dilatation and contraction of the pupil comes about through dynamogenic or inhibitory influence. It has not yet been proven that there is an inhibitory influence. It has not yet been proven that there is a neuron connecting the cerebral cortex with the pupillary centers, but a primary neuron does connect this center with the ciliary ganglion. When the oculo-motor nerve is severed there is descending degeneration to this ganglion.

Angelucci states a neuron extends from the ciliary ganglion to the ganglion cells in the choroid, and from there a terminal neuron passes on to the fibers of the sphincter and ciliary muscles. Thus, he would construct a chain of four neurons, one link from the cortex to the pupillary center, another from the pupillary center to the ciliary ganglion, a third from the ciliary ganglion to the ganglion in the choroid, and a fourth or terminal link from the ganglion in the choroid to the sphincter and ciliary muscles.

From this argument he assumes that contraction of the pupil from light stimulus or convergence is brought about by transference of the stimulus along this chain from link to link. The mydriasis, due to irritating the skin, is caused by inhibition of the function of these neurons. The trigeminus has no direct influence upon pupillary reaction and stimulation of it has no effect if the oculomotor and cervical sympathetic have been divided. The miosis following inflammation of the trigeminus is explained as resulting from the simultaneous injury of the pupil-dilating sympathetic fibers running in this nerve.

He observed that dilatation of the pupil can be brought about in the dog, cat and monkey by stimulation of a particular center. If the cervical sympathetic is stimulated, there is dilatation of the pupil because it acts inhibitorily upon the pupil contracting fibers; whereas, if the cervical sympathetic is destroyed there is miosis due to the withdrawal of nervous energy from the dilator pupillæ, permitting the sphincter to act without opposition. This last observation goes to prove that the normal pupil exists as such by virtue of the tonicity of both the sphincter and dilator pupillæ, for if either is abolished the other immediately asserts itself, causing contraction or dilatation of the pupil.

Muench (*Arch. f. Ophth.*, XLIV. 3, p. 445) lays stress on the absence of elastic tissue in the vessels of the iris; their tortuosity being a passive condition. He avers that the iris is in a state of static equilibrium when this tortuosity of the vessels has been overcome, such as in medium miosis. After death the pupil is dilated, becoming narrower after disappearance of rigor mortis and loss of tonus of the predominating dilator muscle. During mydriasis the tissue of the iris is compressed by the dilator fibers, the vessels themselves having no muscle fibers. He maintains that the physiological ectropium of pigment at the pupillary margin is due to an active contraction of the iris stroma which is connected with the sphincter by radial strands. Dilatation of the pupil takes place more slowly than contraction on account of the opposition afforded by the reefed blood vessels and their contents. (See *Innervation of the pupil*, this section.)

Melancholia. In acute melancholia no abnormalities of the pupils are characteristic. As a rule they appear normal. In chronic senile melancholia spastic myosis has been observed by Minck while mydriasis presented itself in the terminal phase. Others have noted mydriasis to be the rule during the course of the disease. Austin observed the right pupil more dilated than the left but the records do not show any uniform or characteristic behavior of the pupils in melancholia.

Miosis (*Etiology*). J. M. Ball presents the following scheme as a guide to explain miosis. Under *normal* conditions the pupil contracts (1) in response to stimulation of the retina by light, and (2) during accommodation. Under *abnormal* conditions miosis is induced (1) by irritation and (2) by paralysis.

I. Miosis from irritation (spastic miosis) is caused by: (a) Diffuse inflammatory conditions of the brain and meninges, causing a direct stimulation of the motor oculi nerve. (b) Tumors near the anterior corpora quadrigemina or near the center of the third nerve or in its fibers (see *Rigidity*, in this section). (c) In the first stage of apoplexy, in hysteria and in epilepsy. (d) In hemorrhage into the pons. (e) After long continued work, causing spasm of the ciliary muscles and sphincter of the iris. (f) Inflammatory conditions of the anterior portion of the eye (keratitis, iritis, cyclitis, etc.) and foreign bodies in the cornea and conjunctiva. (g) After the use of eserin, pilocarpin, arecolin, muscarin, nicotin or opium.

II. Paralytic miosis due to paralysis of the sympathetic nerve, occurs in: (a) Injuries, apoplexy, tumors or inflammation of the cervical cord. (b) Mediastinal tumors and carcinoma of the esophagus compressing the nerve. (c) Paralysis of the sympathetic nerve, as after excision of the superior cervical ganglion, or traumatism of the nerve itself. (See *Contraction* in this section.)

Methyl-atropin (Bromide of) as a mydriatic. Darier (*La Clin. Ophtal.*, Nov., 1902) states that in bromide of methyl-atropin we have a drug that may transcend homatropin and euphthalmin as a mydriatic. He claims the drug in question has the virtue of atropin as a mydriatic and does not possess the objectionable features. In repeated instillations it has the same mydriatic and cycloplegic effect as atropin. With the employment of a one per cent. solution the mydriasis lasts scarcely longer than twenty-four hours and the effect on the accommodation wears off in a few hours' time. In weak solutions (one-half per cent.) combined with one per cent. of cocain, mydriasis alone is produced.

Ludwig (*Wochensch. f. Therapie u. Hygiene des Auges,* Oct., 1902) experimented with the same drug and reported favorably on its use, stating that it is milder and more evanescent in action than atropin. It is also less exciting to the vagus. (See *Mydriatics* in this section.)

Microcoria—Congenital miosis. Microcoria is a term used to designate the congenitally small pupil in contradistinction to the so-called *miosis* which is a pathologic state. Microcoria, like congenital corectopia, is a developmental fault wherein the pupil is manifestly too small as compared with normal standards. The condition is often found associated with congenitally small cornea. It is sometimes the result of consanguinity of the parents, but may exist where no such consanguinity obtains. In such eyes we may expect to find the lens also undersized or cataractous, and other signs of microphthalmia such as amblyopia due to lack of differentiation of the macula lutea. These pupils will not respond to mydriatic drugs to the usual extent, probably because the muscular elements of the iris are feebly expressed. There is no remedy to suggest.

Macgruder presented a child of six years to the Colorado Ophthalmological Society (January 21, 1911) with contraction of the right pupil from birth. This was associated with amblyopia and convergence. The pupil refused to dilate with atropin, but the pupil of the other eye dilated widely.

Jackson, in discussion, considered the cause to be due to defective centers in the brain.

Migraine, Ophthalmoplegic. One of the varieties of migraine is the so-called "paralytic." In this we have the migrainous attack soon followed by complete paralysis of the third, sometimes also the fourth and sixth, nerves. Charcot in 1890 (*Clin. des Maladies du Syst. Nerv.*, 1892, p. 70) first suggested the name "migraine ophthalmoplegique" and described it as being the motor form of the neurosis. The sensory form is the ordinary scintillating and neuralgic type. The paralytic form is ushered in by severe pain referred especially to the ophthalmic division of the fifth nerve on one side. The pain is very severe in the eyeball and lasts from an hour to several days then the attack of pain is suddenly brought to a close by vomiting. After the painful storm is over the paralysis stage sets in. The paralysis is almost invariably and solely confined to the branches of the third nerve on the same side so that we have ptosis, divergent strabismus, paralysis of the sphincters of the iris and ciliary. Hence the pupil is widely dilated and does not respond to light, convergence or accommodation. This complete ophthalmoplegia lasts from a few days to six or eight weeks and then gradually disappears. The dilatation and paralysis of the pupil are always present but the pupil in the fellow eye always remains normal.

Veasey (*Ophth. Record,* August, 1909, Vol. VIII) reports such a case.

Miosis in prolonged muscular activity. Redlich (*Wien. Med. Wochen.*, Aug., 22, 1908) describes a new pupillary phenomenon which is a marked miosis with loss of reaction to light, occurring during the course of prolonged muscular activity, as in contests of endurance, athletic bouts of long duration, sustained muscular activity after the period of fatigue has been reached, etc. Redlich suggests that the cause might be found in the changed condition of tension and circulation for "if an irritation of the sympathetic were the cause of this phenomenon we would expect to find the pupil dilated and the reaction to light retained."

The writer of this section is inclined to ascribe the miosis found in this condition of excessive and prolonged muscular activity to be the effect of the poisons of oxidized muscle cells in the blood or the catabolic products of worn-out muscle fibers which are known to cause exhaustion and other symptoms of poisoning when muscular activity is continued after the natural period of fatigue has been reached. The poison in question may be myoscin or analogous biproduct of acute cellular disintegration.

Miosis with pupil rigidity. Levinsohn (*Ber. klin. Wochensch.*, 1908, p. 745) considers miosis with rigidity to be a cerebral symptom due to irritation of the Edinger-Westphal nucleus, which is regarded to be the starting point of the centrifugal pathway to the sphincter pupillæ.

"The sphincter nucleus consists of two cell-groups one of which converts light stimulus into pupillary contraction, while the second controls the other sphincter reactions." (Convergence and accommodation.) Disease of the first group causes reflex pupillary rigidity. If *irritation* of the second group is present, the result is a miosis. This miosis must not be confounded with the miosis noted in paralysis of the sympathetic. (See *Argyll-Robertson pupil,* in this section.)

Miosis, senile. Senile miosis, especially the rigidity of the sphincter pupillæ and resistance to myotic drugs as well as restricted dilatation has its cause, according to Fuchs "in the thickening of the connective tissue behind the sphincter," and Meller states "there is hyaline connective tissue at the border of the pupil." (See *Hyaline degeneration of the pupil margin.*)

Miotic tract, Efferent path or centrifugal route. The line of neurons that pass from the sphincter nucleus in the region of the aqueduct of Sylvius and on down in the third nerve to the ciliary ganglion where they communicate with other neurons that perforate the sclera near the optic nerve and pass on to the sphincter pupillæ. (See *Mechanism of pupil action,* in this section.)

Monocular blindness. In single eyes that are blind from atrophy of the optic nerve the pupil responds when the light is thrown in the other eye, but remains fixed if the seeing eye is excluded and the light is thrown in the blind eye. The pupil of the blind eye will also react normally during the effort of convergence and accommodation. (See *Hutchinson's pupil,* in this section, also *Consensual reaction.*)

Motor oculi palsy. Many cases are reported in literature showing the almost uniform behavior of the pupil in cases of third nerve involvement. The pupil usually begins to dilate when ptosis sets in and begins to resume its normal shape and reaction as the ptosis disappears. The normality of the pupil is not completely restored, however, until sometime after ptosis has entirely disappeared and the eye has resumed its normal position and motility.

Sterling (*Arch. of Ophth.,* 1901, Vol. XXX, No. 1, p. 111), states it is possible for all the muscles supplied by the third nerve to be paralyzed excepting the sphincter pupillæ, but that this condition is extremely rare.

Motor oculi nucleus. The nucleus of the third nerve is almost 15 mm. in length and is an aggregation of ganglionic cells located in the floor of the third ventricle and running backward into and along the floor and sides of the aqueduct of Sylvius. This area is made up of separated groups of cells from which nerve fibers supplying the various muscles of the eye supplied by the third nerve spring. This has been worked out and proven by Perlia and verified by others. The association fibers connecting the nucleus of one side of the brain with that of the other have likewise been traced so that there is no real stopping place for nerve stimulus in the brain, the circuit is complete. The impulse is received at the nucleus and transmitted not alone to the nucleus on the other side, but often to conscious centers located in the cortex and a return impulse is reflected to the eye itself. Thus, the light stimulus starts in the retina flashes up the optic nerve to various parts of the brain and returning ends in the iris. The fact that the stimulus of light received in one eye is followed by contraction of both pupils when the fellow eye is in darkness proves the intimate connection and association of the nuclei of the pupil-centers in the two hemispheres. (See *Centers of inhibition,* in this section.)

Motor valence of the pupil. Polimanti (*Arch. di. Ottalm.,* 1906) shows that the threshold stimulation values of the various sections of the spectrum are determining factors in the regulation of pupillary activity and that the motor values of the pupil and the luminous values of the light rays are practically identical. (See *Threshold value and adaptation,* in this section.)

Multiple neuritis. Polyneuritis is generally due to toxic influences exerted through the blood stream. Many diseases, mostly of infectious nature, may elaborate specific poisons in the blood which cause the nerve trunks throughout the body to become inflamed, and a few poisons like arsenic, lead, etc., exert the same influence. The writer has seen one case producing the clinical symptoms of multiple neuritis, including retrobulbar optic neuritis and consequent blindness for ten days, as the result of refrigeration or a common "general cold." The patient after a hot bath went to sleep naked in a room with the windows open and suffered with multiple neuritis of the severest form. The sensory and motor nerves were equally affected.

In the alcoholic type of polyneuritis Uhthoff found the pupils affected in 6 per cent. of his cases. There were pupillary inequality and sluggish reactions noted. Thomsen (*Archiv. of Psych.,* Vol. XXI, case III) found the pathology located in the gray matter of the third ventricle, and expressed in hemorrhagic exudation, etc., and believes the ocular signs in this disease are due to definite cerebral lesions. One pupil is usually more dilated than the other. Sluggish reaction of the pupils to light is rather commonly found in multiple neuritis. Retrobulbar optic neuritis with impaired vision is not so common but when present the pupils are dilated in proportion to the loss of sight. The other symptoms of multiple neuritis so overshadow the pupil symptoms that the diagnosis is usually easily made without help from their condition. (See *Poisons* also *Retrobulbar neuritis,* in this section.)

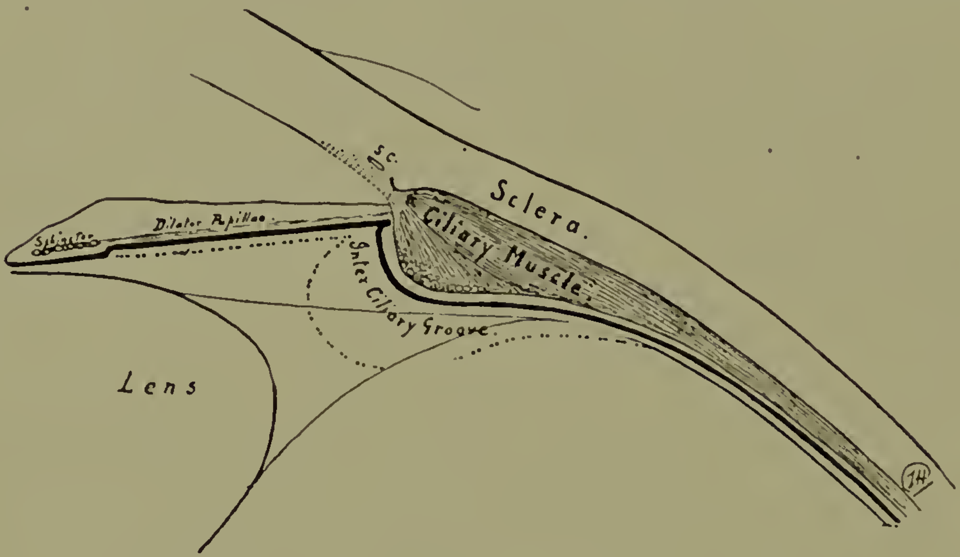
Multiple sclerosis. The functions of the pupils remain normal as a rule, throughout the entire course of multiple sclerosis. This, in view of the fact that other filaments of the third nerve are frequently involved, becomes a valuable aid in diagnosing the disease. Since, however, a placque of sclerosis may and does occasionally involve the sphincter pupillæ nucleus, or indeed the dilator pupillæ nucleus in the medulla, normal-acting pupils are only the general rule to which there are exceptions.

Kampherstein (*Archiv. f. Augen,* 1903, p. 41) states that the pupils present little that is characteristic and hence their behavior in the disease in question is of little or no diagnostic value. He found anomalous pupils in four of his cases, viz., three presented anisocoria and one a faulty reaction to light. Uhthoff (*Ophthalmoscope,* Sept., 1905) reports the ocular symptoms noted in 150 cases of this disease and states the pupils presented but few pathological or diagnostically important phenomena. There was loss of pupil reflex to light in but one case. Miosis with slight response to light was noted in seven cases and pronounced anisocoria in six cases.

Musculature anatomy. The sphincter pupillæ is a narrow band of circular tissue near the free border of the iris, composed of interlacing, non-striated muscular fibers covered in front by connective tissue containing pigment, bloodvessels, nerve strands and lymph spaces in its loose stroma, behind by the brown pigment layer of the iris, known as the retinal pigment or uveal pigment, and bordered on the pupil side by a reflection of this same uveal pigment. The contraction of this sphincter muscle from nervous impulse the result of various stimuli causes the lumen enclosed by it to become smaller in conformity with the well known law that when an annular muscle contracts the space enclosed becomes reduced in size. This contraction on the part of the sphinter pupillæ permits the entire muscular apparatus comprising the mechanism to glide and change its position so that it (the sphincter) occupies a more central area, at the same time there is a distinct movement of the entire iris tissue and a slight change in the color of the iris brought about by the exposure of half hidden crypts and the unreefing of folds that can be noticed near the periphery or root of the iris.

The sphincter pupillæ is an involuntary muscle which, however, can be made to act through voluntary effort, as proven when we compel action of accommodation which is to a certain extent a voluntary act.

The dilator pupillæ is a radiating system of slender spindle-shaped cells containing elongated nuclei and woven into non-striated muscle fibers which have their origin at the annular ligament of the iris at its root and pass in regular converging ridges to be inserted in the outer border of the sphincter muscle and in its posterior structure. It has been commonly taught that the dilator pupillæ is a "sheet" muscle forming a "continuous layer from the ciliary margin of the iris to the sphincter pupillæ." Some discrepancy of opinion exists, strange to say, as to whether this muscle lies *on* the posterior limiting membrane of the iris (Weeks), *in* the posterior limiting membrane (Fuchs), or *anterior* to this membrane (Henderson).



Relation of Iris Root to the Inter-Ciliary Grooves.

The pigment epithelium at the bottom of the inter-ciliary grooves comes almost in direct contact with the mass of the ciliary muscle.

Each interspace is continued on to the back of the iris as a radial furrow, which stops abruptly at a point opposite the outer circumference of the *sphincter pupillæ*. The isolated fasciculi on the *dilator pupillæ* run immediately anterior to the iris furrows. (After Henderson.)

Henderson (see *Glaucoma*, 1910, p. 52), states, "Serial reconstruction of the iris shows that the dilator pupillæ is not a continuous structure, for such would be quite unnecessarily powerful for its antagonistic sphincter, but that it consists of *isolated radial fasciculi* of non-striped muscle fibers arranged around and in front of the radial furrows, *immediately* anterior to the posterior limiting membrane of the iris.

When the dilator pupillæ is stimulated through impulses (generally from within) there is a contraction of muscle fibers which draw the relaxed sphincter pupillæ away from the center toward the periphery and, hence, the pupil is made to dilate. (See *Dilator pupillæ,* this section.)

It is unscientific and incorrect to speak of "contraction of the iris," for if contraction of the dilator pupillæ is meant, the phenomenon known as dilation of the pupil results, whereas if contraction of the sphincter pupillæ is meant, the contraction of the pupil results.

Mydriatics and myotics, Comparison between the older and newer. Schultz (Knapp's *Archives,* March, 1902, Vol. XXXI, No. 2, p. 120) mentions atropin, an alkaloid derived from the root of atropa belladonna, as holding the first place among the old and useful mydriatics. Its action when applied in the eye is to paralyze the sphincter pupillæ and ciliary muscle, thus causing mydriasis and cycloplegia. Since it causes further dilatation than paralysis of the third nerve, it is supposed to also act on the sympathetic, stimulating the dilator pupillæ. Its effect is evident in ten or fifteen minutes and gradually passes off after the third day, ceasing entirely in from six to eight, or occasionally ten, days. In the newly born and the aged its effect is less energetic. In former days when atropin was not well known the ten per cent. solution of extract of belladonna was used.

Duboisin is an alkaloid of duboisia myoporoides, found in East Australia. The hydrochlorate is used in one-half to ten per cent. solutions and acts on the iris and ciliary like atropin. Its action is more rapid than that of atropin and two or three times as strong, but it is more evanescent. Its effect is evident from seven to eight minutes after instillation and reaches its maximum in twenty-five to thirty minutes, lasting about five days. It is more toxic than atropin and should not be used in children.

Hyoscyamin, the alkaloid of hyoscyamus niger, is identical with duboisin. It is used in the form of the hydroiodate in 1/12 to ½ per cent. solution and acts ten times as energetically as the same strength of atropin upon the pupil and accommodation. Its effect lasts from five to seven days. It is more poisonous than atropin.

The newer mydriatics include (1) scopolein or scopolamin. It is the alkaloid of scopolia atropoides and the hydrobromate is used in 1/10 to ¼ per cent. solution. It is five times as energetic in action as atropin, so that a 1/5 per cent. solution has about the effect of a one per cent. solution of atropin. Its effect lasts four to seven days and is very similar to hyoscyamin. Strong solutions have a toxic effect and are therefore dangerous.

Atrocin is similar to scopolein. It has a more intense mydriatic but a less cycloplegic effect.

Homatropin is produced synthetically. Its effect is evident in twelve to fifteen minutes and it reaches its maximum effect in forty minutes, passing off in eight to ten hours, or at most in one day. (1 per cent. solution.) It is less toxic than atropin, although cases of poisoning have been noticed. (See Hotz's case, under *Homatropin* reported in this article.)

Gelsemine, the alkaloid of gelsemium sempervirens, produces mydriasis lasting from twelve to seventeen hours.

Ephedrene, the alkaloid from ephedra vulgaris, is used in a ten per cent. solution and produces a moderate mydriasis in sixty minutes. The accommodation is scarcely affected and the pupil will still contract.

Mydrin is a combined solution of ephedrene and homatropin. It was found that this solution has a more energetic action than ephedrene alone, that it does not last so long as homatropin alone or paralyze the accommodation. It dilates the pupil in 30 to 40 minutes and the accommodation is not much affected. Its effect wears off in five to six hours.

Euphthalmin is a synthetic mydriatic. A 5 per cent. solution will produce mydriasis in from ten to fifteen minutes. The dilatation is *ad maximum* in an hour and the accommodation is somewhat paralyzed. The effect passes off in from four to five hours. It is much used on account of its thorough mydriatic properties and the short duration of its action. (See *Euphthalmin* in this section.)

Mydrol (iodomethyl-phenylpyrazol) in five to ten per cent. solution produces a moderate mydriasis with slight affection of the accommodation.

Cocain we all know about and it need not be described here. (See *Mydriasis due to bellflower, also Methyl atropin,* in this section.)

Of the *myotics,* the first that was used was the extract of calabar bean (physostigma venenosum). In ½ per cent. solution it causes myosis lasting about six hours.

Physostigmin or eserin is the alkaloid of calabar bean. A ½ to 1 per cent. solution of the salicylate, which is less irritating than the sulphate, is used to produce myosis. It contracts the sphincter of the iris and ciliary muscle. The intra-ocular tension is at first increased and then lowered. Its effect begins in from one to two minutes, and is complete in thirty or forty minutes. The effect is abolished in from twelve to twenty-four hours. The solution changes color when exposed to the light for a few days, at first clear it becomes red, and this too without losing its efficiency.

Pilocarpin, the alkaloid of folia jaborandi, is weaker in its effect in contracting the pupil than eserin but it has a similar action. The muriate is used in from one to five per cent. solutions. (The writer uses eserin in ⅛ per cent. solution and pilocarpin in ½ per cent. solution and finds they give about the same effect.)

Arecein, the alkaloid of areca nut, is used in the form of hydrobromate. A 1 per cent. solution will contract the pupil in two minutes and the effect will wear off inside of two hours. It is claimed that it acts more quickly and energetically than eserin and it is believed to be a valuable remedy where quick action is desired without local irritation.

Muscarin from toad stools and rotten fish, and pelletierin from pomegranate, will cause miosis, but these are not used in ophthalmology. (See *Mydriatic drugs,* this section.)

(The subject of Mydriatics—Their actions, their uses and their dangers in ophthalmology is treated very ably and exhaustively by C. A. Oliver in *The Annals of Ophthalmology,* October, 1903, Vol. XII, No. 4, pp. 589 and 613 inclusively.)

Mydriasis (Etiology). J. M. Ball presents the following scheme to explain dilatation of the pupil: Dilatation of the pupil is brought about *normally* (1) when stimulation of the retina is diminished or absent, as in passing from a brightly-lighted to a dark room; and (2) when the eye is directed towards distant objects. If the upper end of the sympathetic is stimulated the pupil becomes larger. Mydriasis or *abnormal* dilatation of the pupil may be divided into two types: (1) paralytic and (2) spastic.

I. Paralytic mydriasis, dependent on the oculo-motor nerve, occurs in: (a) Hemorrhage or tumor in the floor of the aqueduct of Sylvius. (b) In diseases which affect the fibers of the motor-oculi nerve anywhere in its course (e. g., as from sinus thrombosis, glaucoma, etc.) (c) After the use of mydriatic-inducing drugs, such as atropin, duboisin, datura, hyoscyamin, hyoscin or homatropin. (d) In concussio oculi.

II. Spastic mydriasis, dependent on the sympathetic, is found in: (a) Fright. (b) Accumulation of CO_2 in the blood. (c) In the fully developed epileptic and eclamptic attack. (d) Tumors and inflammations of the spinal cord (e. g., in the early stages of tabes). (e) Reflex action from the presence of worms in the intestines, in lead and biliary colic. (f) In tumors of the neck. (g) Melancholia and mania. (h) After the use of cocain. (i) In labor and all painful irritations of any part of the sympathetic, such as renal colic, etc.

In paralytic mydriasis there is no reaction to light, accommodation or convergence. In spastic mydriasis there is usually reaction to light and convergence. Eserine drops will contract the pupil in either paralytic or spastic mydriasis. (See *Dilation abnormal,* in this section.)

Mydriasis from drugs taken internally. It is well known that atropin or belladonna taken inwardly or used on the skin locally will produce dilated pupils. Hyosein given internally will produce the same. The pupils in such cases are not completely paralyzed as a rule but the response to light is feeble. (For a list of the drugs that induce mydriasis when taken inwardly see elsewhere in this section.)

Mydriasis, Traumatic. It has often been observed that a blow on the eyeball with any blunt object may cause the pupil to become dilated. This dilatation may be transient or permanent. In some cases the sphincter pupillæ is ruptured or there is paralysis of action due to damage to the nerve endings in the iris. This subject is treated elsewhere in this section. (See *Dilatation and "Concussio oculi"* in this section.)

Mydriasis due to bellflower (Datura aborea). Fernandez (*Archiv. Ophthal.*, January, 1910, Vol. XXXIX, No. 1, p. 31) had two cases come to him, each with one pupil widely dilated and in each a distinct history was obtained proving the mydriasis to be due to the accidental touching of the eye with a sprig from the common (in Cuba) garden plant known as the "bellflower." The plant is a species of the Datura genus of the solanaceæ family; it is also known as the "judgment's trumpet" and is used in Peru for the preparation of the narcotic beverage called "tonga." In Fernandez's cases pilocarpin restored the normal pupil in two days. (See *Mydriatics* in this section.)

Mydriatic action of cocain and adrenalin. Mattirolo and Gamna (*Klin. M. f. Augenh.*, May, 1913) have studied the effect of a combination of cocain and adrenalin on the pupil. In normal persons the combination acts synergetically in producing mydriasis. In anisocoria cocain alone induces a further dilatation of the wider or normal pupil but has slight effect on the contracted or abnormal one. The subsequent use of adrenalin will cause the smaller pupil to dilate so that the two are rendered approximately equal.

In Horner's syndrome (miosis, ptosis, enophthalmos, etc.) cocain has no effect on the pupil while adrenalin (as noted elsewhere in this section, see *Adrenilin*) will produce wide dilatation of this pupil. In Argyll-Robertson pupils cocain has some effect on producing dilatation but adrenalin will cause it to dilate much further. In mydriasis due to ophthalmoplegia interna cocain had slight effect in causing further dilatation but adrenalin with cocain caused wider dilatation with deformity of pupil contour.

Mydriatics, Synergetic action of combined. Schwartz (*Ann. Ophthal.*, Oct., 1903, p. 711) found he was able to effect a much more pronounced dilatation of the pupil by combining atropin (1 per cent.), scopolamin (3 per cent.), duboisin (3 per cent.) and hyoscin (3 per cent.) than by any of these solutions used alone in cases of chronic iritis associated with cyclitis and synechia. These drugs are known to be quite poisonous in such strengths as he recommends, but there may be cases where the combined solution could be cautiously used with marked benefit. For speedy temporary mydriasis Schwartz recommends a solution of homatropin combined with euphthalmin.

Mydriatic drugs. Oliver, of Philadelphia (*Jour. A. M. A.*, Feb. 21, 1903), states that drugs which are mydriatic in action are to be classified further into four divisions, (1) analgesics, (2) mydriatics, (3) iridoplegics and (4) cycloplegics. He calls attention to the fact that mydriatics may vary in but one or two elemental atoms in their chemical composition, or indeed be isomeric and present different physiological actions on the same ocular structure. The actions of mydriatics are enhanced by bodily repose and subdued light. Cold applications to the eyes diminish the primary and secondary action of mydriatics and hot compresses promote both of these results. In the order of their efficiency the following pure mydriatics are listed: euphthalmin, homatropin, mydrin and ephedrin. The addition of cocain to any of these renders the solution more active. (See *Mydriatics* and *Myotics* in this section.)

Mydriatics and myotics in the intra-capsular cataract operation. Stanculeanu and Rasvan (*Ophthal. Soc'y Trans.*, Heidelburg, August, 1910) experimented to determine the best mydriatic and myotic drugs to employ in their intra-capsular cataract operation. They report that two drops of a 1 per cent. solution of homatropin dropped in the eye the night before gives the proper dilatation for their operation. The incision is made, their capsule forceps introduced and the lens dislocated in the anterior chamber. The cataract is then expressed in its unbroken capsule by means of two broad spatulas one used to make pressure on the lower margin of the cornea the other to press back the upper margin of the wound. After the lens is removed from the eye a 1/200 solution of eserin salicylate in oil is instilled. "On the next day the pupil is contracted more than normally," perhaps the solution of eserin is employed again, but on the second day after the operation a 1 per cent. solution of atropin is employed. This operation in its ideal result leaves the pupil round and central.

Wandless (*Arch. Ophthal.*, May, 1910, XXX, p. 247) states that he is in the habit of using atropin and eserin alternately, or homatropin and pilocarpin in the same way to hasten the absorption of soft cortical substance in the pupil after the cataract operation. He states that the dilated pupil produced by atropin has a tendency to block the drainage channels, which is true enough, hence he uses eserin in solution to contract the pupil and the atropin in solution again to dilate it, repeating the process which he claims tends to keep the absorbable substance in agitation and thus favors its absorption.

Mydriatic conjunctivitis. Atropin in solution dropped in the conjunctival sac over a period of time will, in many cases, especially where the habits are careless and the solution becomes foul, incite a form of conjunctivitis very similar to trachoma or marked follicular conjunctivitis. This fact is so well known that it is now common knowledge. Other mydriatic solutions especially cocain employed by the patient indefinitely will induce a similar state of affairs. Occasionally the writer has seen fresh solutions of this class employed only a few times set up a distinct conjunctivitis. Some patients are particularly susceptible to inflammatory reaction from atropin drops where idiosyncrasy exists, and eserin drops are also quite irritating in the majority of cases.

Kipp (*Trans. N. Y. Acad. Med., Ophthal. Soc.*, Nov. 20, 1905) reported marked conjunctivitis with edema of eyelids in a patient with immature cataract, induced by the twice daily instillation of a 4 per cent. solution euphthalmin for improvement of vision after five weeks' use of the drug. Upon ceasing the use of the mydriatic the conjunctivitis subsided and upon reemploying it a prompt return of the conjunctivitis was noted. H. Knapp had made the same observation in one of his cases.

Mydriatic tract. The line of neurons running from the dilator center in the medulla down the spinal cord to the cilio-spinal center, thence along the first dorsal nerves of the cord to the inferior cervical ganglion, thence to the superior cervical ganglion, thence to the nasal branch of the ophthalmic nerve, thence to the long ciliary nerves to the dilator pupillæ muscle in the iris—all comprising the so-called "sympathetic nerve tract to the iris."

Myelitis, Acute disseminated. Holden (*Archives of Ophth.*, Vol. XLIII, No. 3, May, 1914, p. 231) reports a case of this disease in which there was retrobulbar optic neuritis. The right pupil was 7 mm. and did not react to light but reacted to convergence. The left pupil was 5 mm. with the proper light and convergence reaction. The right eye had no perception of light. The left counted fingers at three feet on the nasal side. The pupils in this disease are not of diagnostic significance for they behave as would be the case where the eyes were blind from any cause. The proportion of dilatation in partial blindness from any cause is followed by the same noted in this case.

Myelitis. Since optic neuritis and subsequent blindness from atrophy often occur in myelitis, it is not to be wondered at that in this condition we find the pupils are dilated and fixed. But the pupils often vary in this disease. One is apt to be more dilated than the other in ratio to the amblyopia present.

If, however, the diseased process involves the last cervical and first dorsal part of the cord, there may be contraction of the pupils (spinal miosis) along with other symptoms due to paralysis of the cervical sympathetic nerves, such as partial ptosis, enophthalmos, etc.

In the early stages of myelitis affecting this part of the cord, irritative signs are manifested on the part of the cervical sympathetic, as expressed in dilatation of the pupils, etc. This dilatation is due to a different cause from that seen in the optic nerve type of the disease for in the latter the amaurosis impairs the light stimulus along the pupillary reflex arc. (See *Diagnostic value* elsewhere in this section.)

Myotics after an iridectomy, Contraction of the pupil with. Since contraction of the pupil is effected by the instillation of certain drugs, which it is claimed stimulate the sphincter pupillæ to action, one would naturally infer that if this annular muscle were cut, as with an iridectomy operation, no such contraction could occur when miotic-inducing drugs were employed. The fact is, however, that escrin drops will induce pupillary contraction in spite of the fact that a segment of the sphincter has been cut away, and its effect is apparently as lasting as if iridectomy had not been employed. The contraction is, however, not so pronounced as regards the uncut part of the sphincter as would be the case in the same segment if no iridectomy had been performed.

Myotonic convergence reaction of Saenger, or bradycoria of Donath. Oloff (*Am. Jour. Ophthal.*, April, 1915) states that Saenger (*Neurol. Centr.*, 1896, p. 1007) proposed the name "myotonia pupillaris" to establish a similarity of the pupil-behavior in certain cases, to the behavior of the voluntary muscles in Thomson's disease (myotonia congenitalis) with which, however, it is not to be confused. They are, pathologically considered, entirely different; this is the generally accepted view although Hoche observed this pupillary phenomenon in a genuine case of Thomson's disease. Oloff reports two cases:

Case I was a boy of 18 of low mentality with negative history as to illness or injury. His pupils were noticed to be unequal since childhood. They were unequally dilated the right being 5 mm. left 7 mm. in diameter. The direct and consensual reactions were present but in the left eye they were somewhat sluggish. On convergence the left pupil slowly contracted as compared with the right and on looking at infinity it remained contracted for one minute longer than the right. Vision, accommodation and fundus were normal and there was no ocular disease, inflammatory or degenerative, present. During the course of the examination a remarkable change took place. The phenomena reversed themselves so that the left pupil became the more dilated and sluggish and the right pupil in turn presented the myotonic phenomenon for it was seen to remain in a contracted state on looking off just as the left had done so shortly before. This play, changing from right pupil to left pupil and back again, was observed repeatedly. The more dilated pupil, whichever it happened to be, was slow in contracting to convergence and remained contracted for a considerable time after relaxing the convergence. The only other symptom referable to the general nervous system was absence of patellar reflexes. Wassermann and cerebro-spinal fluid tests were negative.

Case II was a man aged 44, the victim of chronic alcoholism (periodic). There was a sensitive scar on the left side of his head, corresponding to the suture between the parietal and occipital bones, the result of being hit on the head nine years before with a falling beam. Moderate nystagmus was present. The pupils were not quite round, the right measuring 5.5 mm., the left 3 mm. in diameter. The direct and consensual reactions were present in the right and almost absent in the left. With convergence the left pupil contracted more slowly than the right but in the end became more contracted and when looking off it remained contracted for 30 seconds and then gradually dilated to its former size. The right pupil would promptly dilate after convergence ceased. (Myotonic convergence reaction of the left pupil.) Aside from slight pallor of left optic disk his eyes were entirely normal. The patellar reflexes were absent in this case also. There were no other symptoms of tabes present.

These two cases presented the following symptoms in common: (1) difference in the width of the pupils; (2) monolateral myotonic convergence reaction; (3) absent or nearly absent light reaction in the eye presenting the myotonia of the sphincter, and (4) absent patellar reflexes. The phenomenon under discussion was in the one case associated with the dilated, while in the other with the contracted, pupil. Moreover, in the former case the phenomenon changed from one eye to the other while in the latter it was constantly present in the left eye only. The low mental state of the one case and the head injury sustained by the other seem to indicate a cerebral cause.

Cases presenting the myotonic reaction have been reported by Axenfeld, Saenger, Strausburger, Nonne, Rothmann, Roemheld and Marcus. Dimmer reported a case in 1911 and Lerperger in 1914. Others have followed by Piltz, Strausburger, Saenger and Bach. Dimmer's and Magitot's cases are mentioned below.

The clinical manifestations as noted in a critical survey of these cases were not uniform. There were great variations in the behavior of the pupils to light, convergence, etc, and the histories varied greatly. The only symptom that was constant in all was the prolonged contraction after convergence ceased. In three of the fifteen cases collected, the phenomena were bilateral. Oloff's was the only case in which the myotonic contraction shifted back and forth between the two eyes. In twelve of the fifteen cases reported the pupil of the fellow eye was normal in reaction.

Myotonic convergence reaction should not be confounded with *tonic* light reaction which is a sluggish contraction to light noticed in on-coming amaurosis and sometimes in normal eyes (Bumke and Bach) or with neurotonic reactions described by Weiler in which the pupil contracts for a short time to light and then gives way to rapid dilatation in spite of continued illumination (noted in paralytics).

Dimmer (*Klin. Monatsbl. f. Augenh.*, Sept., 1911) would discontinue the use of the terms "myotonic" and "neurotonic" pupil reactions preferring to regard the conditions they represent to be simply tonic reactions to light, orbicularis contractions, convergence effect, etc., as the case may be. He reports the case of a school-boy with a suicidal tendency who presented the "myotonic reaction." The right pupil was dilated to 8 or 9 mm., there was slow contraction to bright light to 6.5 mm. and further contraction to accommodation and convergence to 3 mm. with slow return to the dilated state upon withdrawing the contracting stimuli. The terms "myotonic" and "neurotonic" contraction of the pupils seem to have come to stay for they describe a form of pupil behavior that is definite. Piltz first described the phenomenon (*Neurolog. Centralbl.*, 1900) and the literature was reviewed and summarized by Rönne (*Klin. Monats.*, Vol. 47, 1909). Magitot of Paris (*Ann. d'oculistique*, April, 1911) also described the reaction in a patient of 57 who was suffering from tabes, in which contraction of the dilated pupil slowly eventuated upon exposure to bright light so that it finally became punctiform and remained so for fifteen seconds after withdrawal of the light. He advances the hypothesis that the lesion in these cases is not in the mesencephalic ciliomotor center, the roots of the dorsal nerves, the inhibitory center in the floor of the fourth ventricle, or in the iris itself but that it is in all probability located in the ciliary ganglion.

Bach regards the lesion to be in the efferent or centrifugal arm of the pupillary light reflex arc in the case of myotonic contraction and in the afferent or centripetal arm of the same arc in the case of neurotonic contraction of the pupil. (See *Pathology of the pupil.*)

Nasal diseases. Weeks (*Trans. of Amer. Ophthal. Soc.*, 1912) reported a case of paralysis of the pupil from a furuncle of the ala nasi. He also noted contraction of the pupil from pressure of an hypertrophied turbinate against the septum nasi. The pupil has also been noticed by Arnold Knapp and others to show abnormality in cases of ethmoidal disease. (See *Sphenoid disease* in this section).

Nasal influence, Inequality from. Feron (*Ophthal. Rev.*, V. 33, p. 282) observed in those cases of anisocoria regarded as being physiological that on the side of the larger pupil the nostril was more permeable. He describes the possible nervous arcs that may explain this rhino-pupillary reflex and suggests that stimuli starting in the sensory zone of the fifth nerve will cause more pronounced reflexes on the side receiving the greater stimulus. The nasal mucosa being supplied by branches of the trigeminal, will be stimulated more on the side that is wider and this stimulation is reflexed to the pupil causing it to be larger than its fellow.

Nerves controlling pupillary size. The nerve fibers supplying the muscles of the iris are derived from the ciliary plexus. For a discussion of the three kinds of nerves which are concerned in pupillary action ((a) sensory, (b) motor, (c) sympathetic), see *General considerations* after the introduction to this section.

Neuroparalytic keratitis. In this disease we note anesthesia of the cornea. The lack of corneal sensitiveness removes from the eye the impulse for contraction of the pupil in response to corneal irritants. Hence, the pupil in this disease is usually slightly dilated but responds to light. This fact goes to prove that there is an intimate relation between the sensory nerves of the cornea and the filaments of the third nerve supplying the sphincter pupillæ. Both sets of nerve fibers are given off from the ciliary ganglion and hence this, which may be called the orbital sensory arc, is independent and complete in itself. The sensory arm being afferent from the cornea to the ciliary ganglion, and the motor arm being efferent from the ganglion to the sphincter pupillæ. This arc is in action in case of phlyctens, corneal abrasions or ulcers, corpus alien in oculi, etc. It is in abeyance in neuro-paralytic keratitis, cocain anesthesia of the cornea, etc. (See *Ciliary ganglion* and also *Argyll-Robertson* Dunn's theory.)

Neurotonic reaction. This reaction is, by Bach, said to be due to a lesion of the centripetal arm of the light reflex and is by him thought to be a transition phenomenon leading to total rigidity in the course of time. It is slow contraction of the pupil following direct illumination of the eye and manifesting itself quite tardily as compared with the normal response to light. After the contraction is established it passes off more slowly than the normal when the bright light is withdrawn.

(This phenomenon is further discussed in *General pathology of the pupil* elsewhere in this section.)

In the newly born. Von Gudden (*Trans. Soc'y Morph. and Phys.*, Munich, Nov., 16, 1909) states that the pupils of the newly born are not contracted during sleep as in adults, but are moderately dilated. After the third month they show more contraction during sleep, and after the ninth month they dilate to the maximum on awakening, as in adults. These phenomena he explains by assuming ''medullary unripeness'' of the conducting nerve fibers in the newly born and on the assumption that the dilatation on awakening is a cortical reflex. (See *Infants' pupils* in this section.)

Normal pupil, Dimensions of the. Tange (*Arch. of Ophthal.*, May, 1908, Vol. XXXVII, No. 3, p. 320) states that Silberkuehl after making a large number of observations of the pupil behavior in normal persons of various ages, found that the pupil has a constant width of 4 mm. until the 20th year, and 3 mm. after the 50th year.

Tange himself examined 1,000 pupils and reports that there is a marked individual difference in the size. It is smaller in the male, in hypermetropia and in increased age; the color of the iris has no influence on the size of the pupil. Myopes have larger pupils than emmetropes until the age of 20, and at the age of 40 the difference is negligible. (See *Dimension physiological,* this section.)

Nuclear paralysis, Monocular mydriasis from. There is in this affection some contraction of the pupil noted when a strong effort at accommodation is made which Knies explains as being due to influx of blood in the iris incident to the ciliary effort. The contraction noted is feeble and short-lasting. There is also some added dilatation of the pupil if the skin near the eye be irritated, which is explained by the stimulation of the sympathetic thus incited.

Nystagmus, Voluntary. In nystagmus nothing noteworthy is observed in the behavior of the pupil but Weekers (*Archiv. d'ophtal.*, Feb., 1912, p. 86) reports the case of a young man desiring to escape military service who by concentrating his attention on his eyes could induce a well-marked horizontal, sharp and rapid nystagmus running twenty to thirty jerks in ten seconds. During the nystagmus there was distinct contraction of the pupils noted. The pupils assumed a markedly oval shape with the long axis vertical. When the nystagmus ceased the pupils became round and normal in size. (See *Changing pupils* in this section.)

Okew's pupils. A condition in which one of the visual axes is deviated upward and the other downward. The sign has to deal with the axes of vision and not with the pupils, but sursum vergens or deorsum vergens being present the pupils are not in the same horizontal plane.

Occlusio-pupillæ is usually the result of a neglected plastic iritis, or, more properly speaking, iridocyclitis. The margin of the pupil becomes bound to the anterior capsule of the lens and the pupil space becomes occupied with an organized exudate which has precipitated on the lens capsule filling the pupil aperture. If the occlusion is complete such eyes present the phenomenon known as iris bombè.

Opacity, Dilatation of the pupil in unilateral corneal. Zur Nedden (*Klin. Monatsbl. f. Augenh.*, LII, p. 844) has seen in each of several cases of dense opacity of the cornea in one eye, a dilated pupil in the other eye. He assumes that the pupil of the eye with the central opacity adapts itself for increased lateral vision by dilatation. This seems true inasmuch as central vision or fusion is lost. The effect of this effort to retain peripheral vision in the scarred eye by dilatation of its pupil doubtless causes the pupil in the unaffected eye to dilate consensually.

Ophthalmoplegia interna congenitalis. Lohman (*Arch. f. Aug.*, 77, p. 43) reports the case of a woman, twenty-nine, who had almost complete congenital iridoplegia in which the right pupil measured 7 mm. and refused to contract by strong illumination, while the same illumination in the left eye, which was normal, caused both pupils to contract to 3.5 mm. He explained this by assuming an insufficient development of the pupillomotor fibers of the optic nerve, which, according to Hess, divide into two branches, one going to the pupillary center the other to a cerebral cortex.

Groethuysen (*Arch. f. Aug.*, 76, p. 265) reports the case of a male aged 18, who had congenital ophthalmoplegia interna, the pupil being widely dilated and immovable since birth.

Ophthalmoplegia totalis or nuclear palsy. This disease usually manifests itself in ptosis first. Soon the excursions of the eyeballs are noticed to be limited; during this state the pupils present no abnormality and the disease is called "ophthalmoplegia externa." Later on, in most cases the pupils show sluggish reaction and slight dilatation, and finally complete dilatation and fixity—"ophthalmoplegia totalis." The pathological anatomy is a progressive degeneration of the cells of the nuclei of the third, fourth and sixth nerves analogous to that found in progressive bulbar palsy. The location of the nuclei involved in ophthalmoplegia interna and externa, being remote from vital centers, renders the disease of much longer duration than in progressive bulbar palsy.

Levinsohn (*Archiv. of Ophthal.,* March, 1901, Vol. XXXII, p. 166) maintains that in spite of the teaching of Uhthoff, Bach and others ophthalmoplegia is in many cases explained only by assumption of a nuclear lesion and is often a sign of tabes, paresis or cerebral syphilis. It is rare among the young, but he reports ophthalmoplegia interna in a boy of sixteen in whom the right pupil was contracted, the left dilated. The right reacted slightly to light, the left scarcely at all. Another case in a girl of nineteen had dilatation of the left pupil while the right was normal. In both of these cases there was unilateral paralysis of the intrinsic ocular muscles. No cause could be found. They did not have syphilis. The affected pupils contracted to eserin with return of accommodation power, from which finding Levinsohn maintained that the lesion existed posterior to the ciliary ganglion. He maintains that a lesion of the oculo-motor nucleus would explain the pupillary manifestations.

Optic neuritis and papilledema. In this condition the visual function, while impaired, is not necessarily so much impaired as to noticeably affect the reaction of the pupil. If then we have a case of dilated pupil in connection with optic neuritis, we may assume that there is cerebral pressure present and that the pupil is dilated because there is distension of the third ventricle and consequent paralysis of the center controlling the sphincter pupillæ (acute hydrophthalmus interna).

Bach states that the pupil in optic neuritis is frequently dilated and that the light reaction varies, though not always, with the disturbance to vision. Even when visual acuity is good the light reaction may be nearly absent. When the visual acuity is different on the two sides one does not always find the pupil larger on the more affected side. When there is tumor of the orbit the size and reaction of the pupil may be influenced because of involvement of the ciliary ganglion or nerves to the intrinsic eye muscles.

Orbital abscess. The pupil in abscess of the orbit will usually react to light if the vision is retained in the eye, but if the stretching of the optic nerve is prolonged and blindness sets in we may expect the pupil to refuse to react to light. The same is true in all cases of orbital disease where the slack in the nerve is taken up by a tense edema of the orbital tissues causing exophthalmos and immobilization of the eyeball. The dilation of the pupil if present may in some of these cases be explained by paralysis of function of the ciliary ganglion due to the cellulitis present.

Organic brain lesions, Diagnosis in. Mignot after an exhaustive study of the subject formulates the rule that complete and persistent abolition of the function of the light reflex arc offers an extreme probability of psychosis with organic brain lesion. (*Vide* Posey and Spiller, *The Eye and Nervous System*, p. 515.)

Oscillations of the pupil (Normal). Schmeichler has noted that if an artificial light in a darkened room is held before one eye while the other is closed, the pupil of the exposed eye contracts and then dilates, re-contracts and re-dilates and so on, the fluctuations being arhythmic and of varying degrees. These oscillations of the pupil do not occur if daylight is used in the test, nor even in the darkened room if both eyes are exposed and fixed on the artificial light. (See *General considerations* introductory to this section, also *Worm-like contractions*, etc.)

Ozena, Mydriatic. Rhoads (*Ophthalmology*, July, 1911, Vol. VII, No. 4, p. 584) reports that 10 per cent. of 300 patients who had had cocain and homatropin drops instilled in their conjunctival sacs in routine refraction work for their mydriatic effect, emitted a characteristic ozena-like odor from their nostrils which was present only during the immediate action of the drug. He offers no explanation and awaits reports from others.

Culbertson (*Ophthalmology*, October, 1911, Vol. VIII, No. 1, p. 15) reports that he too, has observed this odor emanating from the nostrils in almost every patient on whom he has used atropin and remarks the stronger the solution the more disagreeable the odor. He offers an explanation that the atropin dries up the secretions within the nose during its immediate action and that the absence of the nasal secretions permits foul gases to be generated and exhaled from the nostrils.

Paradoxical pupillary reaction. Hess (*Trans. Med. Soc.*, Hamburg, February 9, 1909) exhibited a man of 59 who had contracted syphilis 25 years previously and who exhibited paradoxical reaction of the pupils to light. The pupils in rest were contracted but on making the direct light test they slowly dilated to two or three times their usual size. Cerebral syphilis was diagnosed and an organic lesion was suspected. The function of the right eye was normal, the left was amblyopic with central scotoma and contracted color fields. The optic disks were uniformly gray. Hess interpreted the paradoxical behavior of the pupils as "an action of the dilator whose centers, both cerebral and spinal, were destroyed."

Silex (*Zeit. f. Augenh.*, June, 1900) reports the case of a woman of fifty-two who had had an injury to the back of her head some years previously and whose pupils dilated at once under the influence of light. Disease of the cerebro-spinal nervous system was ruled out in this case, nor was there any sign of hysteria present. He offered the explanation that there may be increased excitability and lowered resisting powers of the entire nervous system and consequently of the pupillary fibers in these cases, so that when light falls in the eye there is rapid exhaustion of these fibers and abolition of function with stimulation of the dilating fibers of the iris.

Westphal and Piltz (*Neurol. Centralbl.*, 1900, p. 149) state that the so-called paradoxical pupillary reaction is elicited when the lids are energetically pinched together (Westphal) or when they are held apart while the patient is told to close them forcibly (Piltz). On ceasing this effort the pupils contract and then dilate. This he states is a physiological process.

Spiller (*Phila. Med. Jour.*, May 2, 1903) reported three cases in which when the patients employed the effort of accommodation the pupils dilated. The paradoxical dilatation of the pupil to light reflex has been much more commonly observed when light was unexpectedly flashed in the eye and an explanation has been offered by Oppenheim (*Neur. Centr.*, Vol. XXX, p. 362) that the flash of light in the eye of a nervous patient would tend to startle him and cause dilatation, but in Spiller's three cases no such explanation will hold. This seems to us a truly paradoxical reaction and there is no explanation that we know of.

(For mydriasis transformed into miosis by bending the head forward see *Changing pupils* in this section.)

Paralysis (flitting) of the pupil. Von Hippel has noticed paralysis of accommodation, mydriasis and pupillary rigidity alternating and returning after several days in healthy subjects of twenty and in two epileptics. He does not ascribe a cause but suspects incipient tabes.

Paralysis of the sphincter muscle of the iris. Bach states that while paralysis of the sphincter muscle of the iris causes dilated pupil this dilatation is not ad maximum. Moreover, individual variations may occur. In unilateral cases the difference which may be marked in the light, may disappear in the dark. It is well known that atropin will cause further dilatation of the pupil than can be produced by paralysis. This is true even after death, proving that the drug has a stimulating effect on the dilator pupillæ and that there are probably ganglionic centers in the iris which are viable for a short while after death.

Paranoia. The subjects of paranoia do not present any constant or characteristic pupil phenomena; in most cases the pupils appear normal. Miosis, inequality, diminished light reflex and deformities of the pupil have been recorded, but we have no guide to the diagnosis of paranoia by anything the pupil may present.

Paresis. The appearance and behavior of the pupils play a prominent part in the early diagnosis of paresis. Dercum states, "one of the earliest phenomena observed in paresis is that of *inequality* of the pupils." Not alone is this noticeable but difference in the ready response to light on careful testing, even in cases where the pupils are equal in size, constitutes a valuable and suggestive sign of incipient paresis. Dercum further states, "In the early stages of paresis, a difference in the promptness of the response to light reaction between the right and the left pupil is almost the rule." Likewise "an impairment in the consensual light reaction may be the *first symptom of a pupillary disorder in paresis.*"

These statements are corroborated by numerous observations carefully followed up and admit of no question. The early diagnosis of paresis rests then with the ophthalmologist who usually sees these patients first on account of the ocular symptoms for which they seek his assistance. A differentiation in the diagnosis between incipient paresis and incipient tabes at once arises. The student will observe that a difference in the size of the pupils is common as an early manifestation in each of these diseases, but in the case of paresis there is tendency to monocular miosis as compared with tabes in which the early tendency is to binocular miosis. It may require some skill to determine which is the pathologic pupil. Given a case, for example, in which the right pupil is 4 mm. and the left 3 mm. the question arises, is the right pupil the normal one and the left contracted, or is the left the normal one and the right dilated? It would seem that the presence of the Argyll-Robertson phenomenon of immobility to light but response to accommodation would fix the diagnosis of tabes, or that the absence of this phenomenon would fix the diagnosis of incipient paresis, but unfortunately in early paresis we may occasionally have Argyll-Robertson pupils while in tabes we may note unequal pupils with sluggish reaction to light in one or both. Moreover, it is not uncommon to find the pupils in each of these diseases to be quite normal in every way. (See Dercum's article on Paresis in Posey and Spiller's text-book on *The Eye and The Nervous System*, 1906.)

Other ocular and bodily symptoms must in all cases be taken into account, for, as stated before, in no disease is there such a thing as pathognomonic pupils.

To illustrate the constancy of ocular signs in the early manifestations of paresis the statistics of Joffroy are here quoted: Number of cases of paresis examined early as to the presence of distinct and characteristic ocular symptoms—227. Number of cases presenting ocular symptoms—212. Joffroy states that the remaining 15 no doubt presented characteristic ocular signs later on. Thus it will be observed that ocular symptoms of paresis are almost invariably present. Of these ocular symptoms the pupils are the most important as affording definite data leading to the diagnosis for, as above stated, we usually find unequal pupils with sluggish reaction to the consensual test.

In summing up the statistics on the subject Dercum rightly states that much allowance must be given to the personal equation of the observer, for what would be called "inequality and sluggish reaction" by one would pass for normal pupils by another less keenly observant; moreover, some allowance must be made for the stage of paresis present at the time of examination; thus a doubtful case of inequality of the pupils at an early stage of the disease at the time the statistics were gathered would soon after, or surely later on, have shown frankly unequal pupils.

Dercum has compiled the records of various observers on the question of pupil inequality as follows:

Siemerling noted inequality in............	27.5	per cent. of cases
Lasegue noted inequality in................	33	per cent. of cases
Morean noted inequality in................	58	per cent. of cases
Rrancotte noted inequality in..............	51	per cent. of cases
Mendel noted inequality in................	60	per cent. of cases
Mobeche noted inequality in................	61	per cent. of cases
Kals noted inequality in..................	62	per cent. of cases
Maril noted inequality in.................	63	per cent. of cases
Ebecke noted inequality in................	64	per cent. of cases
Renaud noted inequality in................	65	per cent. of cases
Seifert noted inequality in................	66	per cent. of cases

Boy noted inequality in	66	per cent. of cases
Regis noted inequality in	66	per cent. of cases
Dontrebente noted inequality in	77	per cent. of cases
Vincent noted inequality in	80	per cent. of cases
Mignot noted inequality in	64	per cent. of cases
Coloian noted inequality in	100	per cent. of cases
Dawson noted inequality in	92.3	per cent. of cases
Komfeld and Bikele noted inequality in	70	per cent. of cases
Gudelen noted inequality in	57.5	per cent. of cases
Raeheman noted inequality in	60	per cent. of cases
Gudden noted inequality in	57.5	per cent. of cases
Wallenberg noted inequality in	53	per cent. of cases
Hillenberg noted inequality in	45	per cent. of cases
A. Westphal noted inequality in	45	per cent. of cases
Joffroy noted inequality in	63.4	per cent. of cases

Inequality and deformity of the pupils are as above stated, among the earliest signs of paresis.

Within the past three years the writer has discovered three cases which subsequently developed pronounced paresis and all three have died from the disease. The characteristic ocular findings were asymmetrical and deformed pupils, sluggish to light and sluggish to convergence and accommodation, along with atrophy of the optic nerves. In each of these there was some miosis expressed more markedly in one eye. Aberrant behavior of the patient which was noticed by the family fixed the diagnosis in these three cases. The diagnosis must rule out tabes, gross organic brain lesions, hysteria and psychoses. Transient abnormality of the pupils is very indicative of paresis. If Argyll-Robertson pupils are present they do not remain so, while in tabes the Argyll-Robertson pupils, if present, are constant from first to last. The consensual reaction of the pupils is frequently impaired in paresis even in the presence of fair direct light reaction.

Extraocular palsies are very rare in paresis. In hysteria and psychoses the sensory reaction test is usually present to a marked degree; if the skin of the neck be pinched or pricked the pupil dilates in hysteria, whereas in paresis it is slightly affected if at all. Hippus and paradoxical pupils are rarely if ever present in paresis but in hysteria, functional insanity, etc., they are often observed.

Paresis, Incipient. The writer has observed anisocoria with unequal response to light long before paresis was suspected by the attending physician, and before any real defection from the normal or esthetic code was noted. The pupils may be equal in size and one may react normally to light while the other reacts sluggishly. This finding in the presence of other symptoms is strongly suggestive of incipient paresis.

Unequal consensual reaction is almost the invariable rule in early paresis. In a well established case neither pupil responds normally to light, both are sluggish, sometimes the more contracted pupil is responsive, the other being fixed. Small, sluggish pupils with other symptoms are also of much value in the early diagnosis. Dercum states "distinct miosis is a symptom of unquestioned value." It must always be borne in mind, however, that the size and behavior of the pupils alone cannot be relied on in making a positive diagnosis of any disease, and in no other disease is this truer than in paresis.

In paresis the pupils are often not constant; they may change in a comparatively short time. A fixed, contracted pupil at one test may be less contracted and show some reaction to light at another test.

The circular contour of the pupil often presents variations in paresis. A faceted contour may be noticed in many cases on close observation. Dawson noted irregularity in outline of the pupil in 94.8 per cent. of cases. Joffroy in over one hundred cases observed deformity of the pupil in 75.2 per cent.

Impaired reaction to light has been studied in series of cases by eighteen different observers (see Posey and Spiller, p. 483) and found to be present in from 26 per cent. to 90 per cent. of cases. The light reflex was entirely abolished on both sides in the larger percentage of these cases, and on one side only in the smaller percentage. A most exhaustive analysis of the behavior of the pupils in paresis was made from a large series of observations by M. de Montzel and abstracted in full by Dercum (Posey and Spiller, p. 483); the reader is referred to this interesting and valuable contribution on the subject. From M. de Montzel's studies the following conclusions were drawn:

(1) The light reflex was more frequently abnormal than normal.

(2) Exaggerated reflex was exceptional.

(3) There was only a slight difference in the frequency of occurence of the diminished and the lost reflex.

(4) The changes in reflex were identical on both sides; only exceptionally was the reflex lost on one side and normal on the other.

(5) In the early stage the normal reflex was more frequent than the abnormal, while in the later stages abnormal reflex was the rule.

(6) Exaggerated and unequal changes on the two sides were al-

ways present in the initial stages of the disease; the frequency of this was proportionate to the progress of the disease.

(7) The reflex was abnormal in one-fourth of the remissions.

(8) Exaggeration was only seen in the expansive and mixed forms.

(9) An abnormal reflex was always noted in the traumatic cases.

(10) In all cases abnormal reflex was more frequent than normal.

In series of cases studied by various observers the percentage of miosis in this disease varied from 7.2 per cent. (Kaes) to 38 per cent. (Vincent) and 39 per cent. (Marie). The miosis noted is slightly different from that seen in tabes, in that on loupe observation slight reaction to light is often present; moreover, the miosis is noted to be unequal in the two eyes, a fact not often observed in tabes.

Among twenty-four cases examined by Cooke (*Ophthalmology*, October, 1916, Vol. XIII, No. 1) it was found that the pupils did not react to light among 12.5 per cent. While among twenty-eight cases of dementia præcox the pupils did not react to light in 30 per cent. and among fourteen cases of maniac depressive insanity the pupils did not react to the light in 15 per cent.

There is not much diagnostic significance therefore, in the pupillary behavior among these three diseases. As stated above, the most valuable and constant pupillary sign of paresis is impaired consensual reaction with anisocoria.

Slight dilatation of the pupil along with deformity of its outline especially noted in one eye has been observed in series of cases of paresis in percentages varying from 3.6 per cent. (Kaes) to 44 per cent. (Marie). Mydriasis is not so frequently manifested as miosis and when present is apt to pass away and lapse into the normal sized, sluggish or fixed pupil, or indeed pass over into miosis. Mydriasis in degenerative brain lesions is more often indicative of syphilis, ophthalmoplegia interna, gross brain lesions and insanities than in paresis. In cases of juvenile paresis dilated irregular and sluggish pupils are the rule; this is in sharp contrast with what we find among adult or senile cases.

In paresis the pupil reacts to the effort of convergence and accommodation long after the light reflex is lost. In this regard the reaction is similar to that in tabes. In tabes the pupils almost invariably react to convergence and accommodation no matter how pronounced the miosis is, while in well established paresis the pupils in a large percentage of cases do not respond to accommodation effort; de Montzel found the pupils abnormal to this test in from 36.7 per cent. in early cases of paresis to 83.2 per cent. in advanced cases and in the depressive forms in 100 per cent. of cases.

Pathology (General) of the pupil. L. Bach. (*Zeitsch. f. Augenh.*, Vol. XVIII No. 6) states that the pathology of the pupil has not been accorded the interest that it deserves. The theme divides itself into three main divisions:

I. The pathology of the pathways for contraction to light.
II. The pathology of the pathways for pupillary dilatation.
III. The pathology of reflex immobility.

I. Pathology of the light-contraction paths.

Beginning with the centripetal portion of the pupillary light reflex arc we note: (a) that in unilateral destruction of the retina or optic nerve the direct pupillary reaction to light in the affected eye is absent though the consensual reaction remains. The pupil of the blind eye is wider than that of its fellow; the convergence reaction is retained as well as the reaction to sensory and psychic stimuli.

(b) In bilateral destruction of the retina and optic nerve the direct and indirect light reactions are absent from both eyes and the pupils are enlarged. The convergence reaction, though often slight, is present. In variations from this behavior, if simultaneous lesions of the centrifugal channels can be excluded, we must think of an elective affection of the pupillary fibers of the optic nerve.

Bach thinks that the nomenclature of complete inaction of the pupil given by Häddeus, viz., "reflex deafness" (reflex taubheit) is not adapted for teaching purposes and he suggests the use of the term "amaurotic immobility" or "pupillary inaction in peripheral amaurosis."

Another disturbance of the pupillary reaction occurring in disease of the centripetal fibers for the light reflex, namely, hemianopic pupillary inaction, the existence of which seemed fairly established by numerous studies in the last two decades, is again rendered uncertain by the recent studies of C. Hess. (See *Wernicke's test.*)

While normally both pupils react to light when either half of the retina is illuminated, in certain pathological conditions the illumination of a non-seeing retinal-half is followed by absent or nearly absent reaction of both pupils. Generally hemianopsia is bilateral, rarely unilateral. The convergence reaction as well as the reaction to psychical and sensory stimuli remain normal. In spite of the complete loss of the reflex irritability of one-half the retina the ordinary examination of the pupillary reaction discloses only a diminution and not abolition of the light reflex on account of the diffusion of the light within the vitreous chamber thereby stimulating the seeing half of the retina.

The cause of hemianopic pupillary inaction may be: (1) Changes in the eye itself which cause abolition of this function in one-half of the retina. (2) Unilateral lesion of the optic nerve. (3) Affection of the chiasm. (4) Affections of one optic tract. (5) Disturbance of the anterior arm of the quadrigeminum, or in the area between the oculomotor nucleus and the quadrigeminum.

If the lesion affects one optic tract at any part where the pupillary and optic nerve fibers are still united, hemianopic pupillary inaction and hemianopsia are both present. Immediately anterior to the corpus geniculatum there is separation of these fibers, consequently hemianopsia may occur without pupillary inactivity if the lesion is beyond the point of separation of these fibers.

Absolute (total, complete, universal) pupillary inaction. There may be complete lack of pupillary response from a lesion in the centrifugal paths, namely, in the oculomotor nucleus and peripherally therefrom. We usually term this absolute pupillary inaction. In absolute inaction the contractions of the pupil to direct and indirect light, and also to convergence, and the dilatation of the pupil to sensory and psychic stimuli, are absent. Absolute pupillary inaction is generally accompanied by palsy of the sphincter of the iris and possibly by a spastic mydriasis due to irritation of the sympathetic. Palsy of the sphincter of the pupil may be isolated or associated with palsies of other ocular muscles, especially the muscle of accommodation. All possible variations may be seen. The lesion causing absolute pupillary inaction may be located anywhere along the centrifugal fibers from the nucleus to the sphincter iridis muscle. Likewise a disturbance of the cerebral cortex may affect the conduction power of the oculomotorius.

In the differentiation between palsy due (a) to lesions of the ciliary ganglion and short ciliary nerves, or (b) lesions posterior to the ciliary ganglion, the use of eserin is recommended on account of its known stimulation to the end organs of the short ciliary nerves. In the former case its action is negative while in the latter it is positive. This statement is not fully accepted and requires further systematic study.

Absolute pupillary inaction caused by palsy of the sphincter may be due to various diseases, principally infections, intoxications and traumatisms; it may also be hereditary. Recent investigations have revealed its presence in hysteria, epilepsy and in certain maniacal conditions. Pupillary inaction may also be due to local causes such as high intraocular tension and synechiæ between the iris and lens.

Neurotonic and myotonic reaction (Saenger). Neurotonic reaction differs from the typical behavior of the pupil seen in disturbances of the centrifugal or centripetal pupillary pathways. Its characteristic is an abnormal continuation of the state of pupillary contraction or dilatation. The change between these two states may occur normally or haltingly. This reaction is usually accompanied by other symptoms of organic lesions. Generally in the neurotonic reaction there is a lesion of the centripetal, and in the myotonic a lesion of the centrifugal reflex tract. The reaction takes place only after prolonged action of the light or convergence impulse. Both disturbances require further study. (For discussion of myotonic pupillary reaction see elsewhere in this section under *Myotonic*.)

II. Pathology of the pupillary dilatation centers and tracts.

Pupillary dilatation was, until recently, thought to be practically entirely due to the influence of the fibers of the sympathetic. Recently it is considered more probable that pupillary dilatation is more especially due to inhibition of the oculomotor nerve supplying the sphincter. Pupillary dilatation may therefore be due to: (1) Stimulation of the cervical sympathetic (active dilatation), and (2) Pathology of the centers or tracts in connection with the oculomotor nerve supplying the sphincter (passive dilatation).

(1) Active pupillary dilatation. A maximum dilatation of the pupil will follow strong irritation of the sympathetic even when the eye is exposed to strong light. Spastic mydriasis, as it is called, is very rarely found but the opposite condition, viz., the so-called *Horner symptom-complex* noticed in complete paralysis of the sympathetic is rather common. This latter comprises miosis, ptosis, enophthalmos and lowering of intraocular tension. These symptoms are not always present in the same degree and occasionally some are absent. The reaction of the pupil to light and convergence in miosis caused by paralysis of the sympathetic is still present and prompt, its excursion being narrower. Exact studies of the quantitative and qualitative relations of this reaction are important. The Horner symptom-complex has frequently been produced experimentally in animals, and recently as a therapeutic measure in man, by removal of the superior cervical sympathetic ganglion or by the cutting of the fibers of the sympathetic in the neck. It is noteworthy that these phenomena occurring immediately after the operation are, as a rule, of short duration. Soon after the operation the pupil becomes wider again and is especially wide under the influence of narcosis, pain, fear, convulsions and asphyxia. These facts are of great interest and

value as constituting contra-indications for the removal of the superior cervical ganglion for the relief of glaucoma in man. The dilatation of the pupil occurring after sympathectomy is explained by "automaty." We understand by this term the ability of the smooth iris muscle to become active under the influence of the circulation. The stimulation of the blood acts peripherally on the muscle itself. This stimulation is occasioned by the degeneration of the nervous elements of the cervical sympathetic resulting from the operation. It does not begin immediately after section of the sympathetic but manifests itself about twenty-four hours later.

(2) Passive pupillary dilatation: Passive pupillary dilatation is characterized by the absence of pupillary dilatation to sensory and psychic stimuli. There is absolute immobility to all reflex tests. The underlying causes differ widely.

In passive pupillary dilatation the pupillary sphincter is palsied and while the pupil is not *ad maximum,* wider dilatation is impossible. Psychic and sensory stimuli have no effect on the pupil. The seat of the disturbance is either in the muscle itself or in direct connection with its nerve tracts and centers. From this it would appear that lack of response in passive pupillary dilatation is always due to palsy of the sphincter pupillæ. Experimental studies in animals do not altogether harmonize with the clinical observations in man. Some observers state that passive pupillary dilatation is impossible after section of the oculomotor nerve, while others state that in addition to section of the short ciliary nerves or removal of the ciliary ganglion (equivalent to oculomotor section) severance of the cervical sympathetic nerve is required before this result is obtained. This apparent contradiction can be explained by a difference in procedure and the interval of observation after the performance of the operation. Immediately after cessation of the sphincter innervation there is a cramp of the dilator which is soon gradually lost.

By exact clinical study of absolute immobility in its various stages and by further study of experimental results, this apparent contradiction will be explained. The question will then be definitely answered as to whether passive pupillary dilatation is complete through sphincter palsy or if dilator palsy is also required.

Aside from the above described form of absolute inaction we may observe a failure of passive pupillary dilatation in the so-called reflex pupillary immobility. In this type of pupillary phenomenon the cause of the disturbance is not in the muscle nor in the directly connected nerve centers or tracts, for the lesion is beyond the nucleus of the oculomotor nerve. Experimental study has taught us that a lessening of oculomotor tone follows withdrawal of sensory and psychic stimuli. Perhaps the medulla oblongata plays a part. It may therefore be inferred that the failure of passive pupillary dilatation in reflex immobility may be due to damage of the cerebrum or tracts leading to or from the same. The failure of passive pupillary dilatation has led us to an interesting and diagnostically important pupil anomaly, viz., reflex pupillary inaction.

III. Pathology of reflex pupillary immobility.

In typical cases of reflex iridoplegia the direct and indirect light reactions, as well as the dilatation of the pupil by sensory and psychic stimuli, are absent while the convergence reaction remains normal and may in fact be increased and more promptly so on account of the failure of reflex dilatation. Miosis is usually present. (Argyll-Robertson phenomenon.) Reflex inaction is nearly always produced gradually over a period of months, even years.

Variations of the clinical phenomena: Many variations of the clinical picture occur. They are caused by the fact that the manifestations are not always the same on both sides. For a long time they may be unilateral and, furthermore, owing to the fact that the component factors forming reflex immobility namely, disturbance of the light reaction on the one hand and absence of reflex dilatation on the other, they are neither equally affected in the same degree nor at the same time.

Pupillary inequality. Frequently this condition is observed in reflex immobility; it occurs in about 50 per cent. of cases. It is explained, aside from other pupillary disturbances, by unequally advancing stages of the disturbing process.

Changes in pupillary width. The pupillary widths may vary on different days. The changes are usually small, according to Bach's experience they are only observed in cases where reflex immobility is in the process of formation. Many reports in literature concerning changes in pupillary width in reflex inaction are doubtlessly explained by the observers not adhering to similar methods of observation.

Intermittent reflex immobility. The same failure of careful study may explain the so-called intermittent reflex immobility. Slight variations to light reaction have been observed by Bach but, he states, typical cases of intermittent immobility, never.

Change in shape of the pupil. A very common though not characteristic phenomenon in reflex immobility is lack of rotundity of the pupil. The cause of deformed pupils cannot be explained with certainty for all the theories that have been offered have important objections. (See *Deformed pupils* in this section.) Perhaps the systematic use of mydriatics and miotics will assist in affording an explanation.

The lid closure reaction. By this term we understand a contraction of the pupil synchronous with the closure of the lids. This will be particularly observed in reflex immobility for the disturbing influence of the light reaction is then absent. A certain diagnostic importance is attached to the fact that this reaction is sometimes exceedingly prompt and extensive in reflex immobility. An ignorance of this fact not infrequently leads to a false diagnosis,—paradoxical pupil reaction for instance.

The causation of miosis. In the clinical picture of reflex immobility miosis is found. One would naturally imagine that pupillary dilatation instead of contraction would be present because of the absence of the light reaction. Various hypotheses to explain this miosis have been advanced. Bach thinks the theory advanced by Erb has most merit, namely, that it is due to withdrawal of sensory and psychic stimuli. Further studies in cases of reflex immobility that are in process of formation are needed. Bach observes that the miosis is similar to that seen in sleep or after the administration of narcotics.

The causation of direct and indirect loss of light reflex. The majority of authors believe that this is due to destruction of the fibers leading from the optic tract to the nucleus of the oculomotor nerve. This localization does not explain the clinical symptoms of the reflex immobility. Bach believes that neither a lesion of the corpus quadrigeminum of the Edinger-Westphal nucleus nor of the oculomotor nucleus is a causative factor. One could presume an elective disease of the fibers in the centrifugal arm of the light reflex arc but this would leave the miosis found in reflex immobility without explanation. Bach believes that there is an inhibitory center for light contraction and reflex pupillary widening situated in the medulla oblongata.

Differential diagnosis between reflex and absolute pupillary inaction. Many authors consider the absolute inaction an advanced stadium of reflex immobility and in this conception the absolute immobility of progressive paralysis and tabes palsy is called total reflex immobility.

In most cases it is impossible to state that absolute immobility has followed reflex immobility for in any case a similar cause and localization cannot be proven. Until this can be demonstrated Bach believes that these conditions should be differentiated. The typical picture of reflex immobility may remain unaltered for years. It is not the rule that absolute inaction will follow eventually.

Occasionally the differential diagnosis between reflex and absolute immobility is rendered difficult because the pupillary anomalies are not fully developed, or they are in a state of retrogression. Particularly common is the mistake of assuming a regression stage of absolute immobility to reflex immobility. It is possible, for instance, in regressive absolute immobility, to have a stadium in which the light will not contract the pupil but in which the stronger acting convergence impulse will cause contraction; this contraction is rather slight whereas the contraction with convergence in true reflex immobility is very prompt and of greater extent. (See *Rigidity* in this section.)

Paradoxical light reaction. By this we understand a pupillary dilatation upon exposure to light or a contraction in shadow. Bach believes that in the majority of cases a false diagnosis has been made because of insufficient knowledge of pupillary phenomena and incomplete examinations.

Changing pupils. This rather rare affection is divided clinically and genetically into three groups. In the first group belong those cases in which one pupil changes its diameter varying from a greater width to a less-than-normal without the action of light or convergence. These changes occur at regular intervals of about one minute and last a certain time. This clinical picture is seen in eyes which have congenital oculomotor palsy, or in those developing the same in early childhood. There are certain connections between this disease and the post-hemiplegic form of hemiathetosis.

In the second group one pupil, and that the normal one, only changes in diameter in accordance with the circumstances of the examination while the pathologic pupil remains stationary. The unequal pupillary width depends upon unilateral sphincter palsy.

In the third group the relative size of the pupils is changed at various times. As there is usually an evidently greater width of one pupil or the other, the term "changing mydriasis" is usually applied. The early observations of this change were noted in tabes and progressive palsy and were thought to indicate a serious prognosis. Recent observers have also noted this condition in functional neuroses and in apparently healthy individuals, which would indicate its harmlessness.

Hippus iridis. Physiologically the width of the pupil oscillates more or less. Bach agrees with Caupp in the following definition: Hippus iridis consists of rhythmic contractions and dilatations of the pupil, changing every one to three seconds and occurring independently of light, convergence, psychic or sensory stimuli. The excursions are usually of the same degree varying as a rule from two to three mm. Hippus is usually bilateral, very rarely unilateral. It is seen in many varieties of diseases of the cerebrospinal system, and so far as we know has no pathognomonic significance. Its etiology is obscure.

Bach further states (*Oph. Review,* March, 1909) that the classification and nomenclature of pupillary disturbances is a subject with which all standard text-books on ophthalmology deal. Interference with the normal action of the sphincter, apart from intraocular conditions, such as iritis, is either of centripetal, centrifugal or of reflex origin. Since, however, the degree of inactivity is by no means dependent necessarily on the degree of amaurosis it would seem better to call these cases simply "centripetal" or "afferent." On the other hand cases of inacvitiy due to paralysis of the third nerve or to affection of the motor nuclei are called by Bach "absolute," since they involve the convergence as well as the light reaction. Inasmuch as the paralysis due to this cause may be only partial, however, it would serve better to call these cases "centrifugal" or "efferent."

The term "reflex inactivity" should be restricted to cases showing the Argyll-Robertson pupil; in these cases the central mechanism is defective but both afferent and efferent paths are intact. Interferences with the dilating mechanism may be similarly classified. First, there may be an absence of afferent impulses from all over the body and the pupil becomes contracted as in physiological sleep. Second, the sympathetic may be paralyzed and the pupil of the affected side becomes relatively small owing to paralysis of its dilator muscle. Third, there are the cases quite analogous to those of Argyll-Robertson pupil where, though the senses are awake, the inhibitory apparatus that normally prevents the third nerve from fully contracting the pupil in waking hours is ineffective or, according to the other view, the reflex mechanism by which the fibers of the sympathetic nerve to the dilator muscle are stimulated, is inhibited. Spinal miosis is an example and it is an interesting fact (to which Bumke and Bach agree) that in tabes the loss of the light reflex is commonly associated with the loss of reaction to sensory and psychical stimuli.

The subject of tabes necessarily occupies an important place in any work on the pupil. Is its reflex inactivity confined to this disease alone or does it occur in others? Authorities generally ascribe it to one of three causes, viz., tabes, general paresis, or syphilis. Inasmuch as the first two diseases are as a rule post-syphilitic and as the pupillary symptom may remain an isolated symptom of tabes for many years it is not improbable that *all cases* of true reflex inactivity are due to syphilis. The diagnosis may be difficult or even impossible in cases of retrogressing partial centrifugal inactivity for, just as the reaction to convergence is slower to disappear under the action of homatropin than the reaction to light, so in a case of partial paralysis of the third nerve the reaction to light may be wholly lost while there is still some reaction to convergence. In tabes, however, the fact that the loss of reflex is so generally binocular, the miosis which is commonly present and the loss of reaction to sensory stimuli, constitute the available diagnostic points. As to the anatomical basis of these symptoms we are not as yet sufficiently informed although much speculation is rife. The results of post mortem examinations are most confusing. The third nerve nucleus, the corpora quadrigemina and the roots of the third nerve have each been said to be involved, but each of these structures may be perfectly normal. There is considerable evidence to show that degeneration of the posterior columns of the cervical cord is constant but there is also considerable evidence that it is not. This, however, is the region to which Bach himself looks for an explanation—not as others have done, via the sympathetic but by diseases of conjectural "centres" at the lower end of the medulla oblongata which he calls "inhibition" centres and which he was led to believe exist from observations made by experiments on cats. Bach first supposes that the normal action of sensory stimuli is induced by inhibiting the action of the third nerve and then suggests the existence of two new "centres," the function of one of which is to inhibit the inhibitory action of the other.

In a final section on the clinical examination of the pupil Bach recommends that as a matter of routine, quantitative observations should be made of the diameter of each pupil: (1) in dim light, (2) in bright light with both eyes open, (3) in bright light with the fellow eye shut and (4) in convergence; the comparison being made at each observation with a standard scale.

Examples illustrating the value of Bach's scheme of testing the pupillary reactions:

Example I.

	Right	Left
Dull light	5.5	5.5 mm.
Bright light. Both eyes open	2.75	2.75 mm.
Bright light. Fellow eye shaded	3.0	3.0 mm.
Convergence	2.5	2.5 mm.

The above case is normal.

Example II.

	Right	Left
Dull light	6.0	5.5 mm.
Bright light. Both eyes open	3.25	3.0 mm.
Bright light. Fellow eye shaded	6.0	3.0 mm.
Convergence	2.75-2.5	2.5 mm.

The loss of direct reaction on the right side is here the striking feature pointing to "amaurotic" inactivity. Slight inequality of the two pupils from this cause is, according to Bach, common.

Example III.

	Right	Left
Dull light	2.0	4.75 mm.
Bright light. Both eyes open	2.0	2.75 mm.
Bright light. Fellow eye shaded	2.0	3.0 mm.
Convergence	1.5-1.0	2.5 mm.

Here we have complete loss of the light reflex combined with a small pupil on the right side only—reflex inactivity both to light and sensory impressions

Example IV.

	Right	Left
Dull light	5.5	5.5 mm.
Bright light. Both eyes open	4.5-4.25	2.75 mm.
Bright light. Fellow eye shaded	4.5	3.0 mm.
Convergence	4.25-4.0	2.75 mm.

This is a case of incomplete paralysis of the centrifugal path on the right side.

To these routine tests those for sensory and psychical reflexes must be added in some cases, but for clinical examination no elaborate mechanism is needed unless it be for the hemiopic reaction, and for this an apparatus devised by Hess is recommended.

Pectinate ligament, The pupil in rupture of the. When the annular ligament is ruptured or torn from its scleral attachment, which is an accident more common than is recognized, Buchanan (*Ophthalmoscope,* Nov., 1907) declares that the anterior chamber is filled with blood, which, after absorption, reveals the pupil to be no longer circular and of uneven depth, and usually dilated and paralyzed.

The ciliary body is driven back into the vitreous chamber, by the blow on the eyeball. The diagnosis is made by the dilated and irregular pupil with a distorted plane of the iris. The ocular tension is usually lowered due to escape of aqueous through the rent leading to the suprachoroidal space, and detachment of the choroid, usually temporary, should be suspected. Rupture of the choroid and detachment of the retina should be looked for. (See *Retroflexion* of the iris in this section.)

Perforation of the cornea, The pupil after. After a perforation of a cornea from an ulcer or a wound the iris immediately springs into the opening, being carried there by the gush of aqueous, the sudden lowering of the tension and the forward movement of the lens, aided by a spasm of the muscles of the eyelids. For a while there is a fistulous tract established which tends to hold the soft iris tissue in the opening. Plastic inflammatory material soon closes the opening sufficiently to permit the return of intraocular pressure and then the aqueous chamber is reestablished.

In such instances the pupil is always distorted and displaced, depending on the location and size of the perforation, and as a consequence the plane of the pupil and iris may be wavy or oblique. Examination with an ordinary condensing lens renders the diagnosis in such a case very easy. Such a pupil proclaims by its condition the events of its past history which caused the corectopia. Some of the eyes presenting this picture (leucoma adherans) retain very good if not normal vision in spite of the distorted pupil aperture, but many are blind from the glaucoma which develops secondarily.

Percussion, Exudation in pupil from. If the eye of a rabbit be struck by the fingers repeatedly, as in percussion, the pupil will contract and soon become covered with exudation. (Vol. II, p. 345, Roemer's text-book on *Diseases of the Eyes.*)

Persistent pupillary membrane. In the normal sequence of embryologic events that part of the anterior vascular sheath of the lens in embryo which occupies the pupil area disappears a month or two before parturition, leaving no vestige. In some instances a fiber, several fibers, a loop, a fringe or some anomalous vestige of the pupillary membrane persists and is seen in the pupil as a congenital abnormality, visually of no practical significance but of interest and affording a curious exhibition for the family and friends who are wont to ascribe it to a fanciful resemblance to some object in the outside world to which their imagination conceives a resemblance, and its occurrence is apt to be ascribed by them to "maternal impression" or "mother mark." With this usually goes a story of real or fancied incident which is very plausible to the wonder-seeking populace desiring mystery and occultism where open facts would be unwelcome and preferring romance to facts. The aberrant tags, fibers, or in some instances only mere pointed elevations from near the pupil margin, are by common consent called "persistent pupillary membranes." Franke (*Archiv. of Ophth.*, XXX, p. 4) reported their presence in 32 out of 3,508 persons, or 0.9 per cent. as follows: (a) In 18, mere filaments. (b) In 14, actual membrane. Among 29 of the 32 the condition was present in one eye only. In 3 it was bilaterally expressed. These figures compare similarly with those of Stephenson.

Stephenson (*Trans. Ophth. Soc. of U. K.*, XIII, p. 139) reports 68 cases among 3,414 examined or 1.7 per cent. with the conditions bilateral in 13.

The various forms of persistent pupillary membrane are classified by Collins and Mayou (*Pathology and Bacteriology of the Eye*, p. 76) as follows: 1. Fibers arising from the smaller circle of the iris and uniting to form a membrane at the center of the pupil. 2. Fibers arising from different points of the circumference of the smaller circle of the iris and stretching across the pupil to form a delicate network in front of it. 3. Fibers running tangently between two points in the smaller circle of the iris. 4. All the toothed projections of the smaller circle prolonged inward and projecting beyond the pupillary margin. 5. One or more fibers attached to the smaller circle of the iris floating free at the other extremity. 6. A loop formed in front of the pupil. 7. One or more fibers arising from the iris attached to the capsule of the lens; sometimes spoken of as a capsulo-pupillary membrane. 8. One or more fibers arising from the iris attached to the posterior surface of the cornea. (During the stage when the budding mesoderm forms the iris there is no aqueous chamber, the cornea being in contact with the lens. When aqueous forms a fiber is left adherent to the posterior surface of the cornea in front and the lens capsule behind.) 9. A piece of membrane, pigmented or unpigmented adherent to the anterior capsule of the lens without any attachment of the iris.

When any of these persistent membranous filaments are present we may find evidences on the part of other intraocular tissues of congenital anomalies, e. g., coloboma, a notching of iris, polycoria, discoria, corectopia, subluxatio-lentis, forms of congenital cataract, coloboma of choroid, retina or optic nerve and microphthalmus. Most of the cases seen by the writer have presented no evidence of congenital anomaly other than the persistent pupillary membrane.

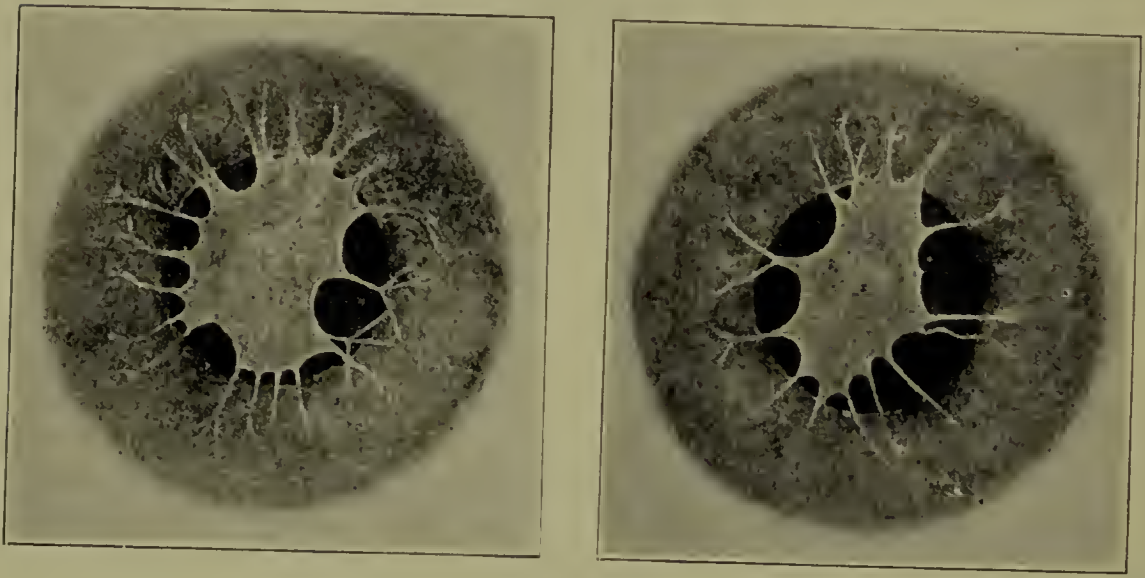
deSchweinitz and Holloway (*Ophth. Sec., Col. of Phys.*, Phila., Dec. 19, 1912) demonstrated retained pupillary membrane, which they believe resulted from iritis in utero. The patient was a boy sixteen years old who gave no history of an inflammation of his eye. The eye was fully formed. There was a pigmented deposit on the anterior capsule. There was also a strand or filament of tissue like that seen in persistent pupillary membrane.

Terrien and Mawas (*Arch. d'ophtalmol.*, July, 1916) report a very rare case of congenital pupillary membrane which was of such dimensions as to reduce the sight to between 1/10 and 1/15. The condition of the pupils is shown in the accompanying illustrations. These membranes which were not adherent to the anterior capsule of the lens but which obstructed the entire pupillary aperture when the pupil was in a medium state of contraction were attached to the lesser circle of the iris by a number of fine strands or "guy ropes" as shown. In the right eye there were twenty of these strands of insertion and in the left eye fifteen. During contraction of the pupil the strands became relaxed and allowed the membrane to be displaced forwards toward the cornea "much as a sail might be bellied forward to the wind." The operation for removal of this obstruction consisted in cutting the lower strands by means of a narrow-blade Graefe knife which had been entered at the limbus in the horizontal meridian. As soon as they were cut the membrane retracted upwards revealing a beautiful black pupil.

A wait of a half-hour allowed the aqueous to reform and the upper strands were cut in a similar manner. Section was then made at the original puncture and the membrane was grasped and removed by the aid of forceps. The vision, which at first showed no improvement, became normal at the expiration of twenty-five days. It was thought the gradual improvement of vision up to the normal occurred as the result of development of the elements of the macula lutea.

Phlyctenular keratitis. The prominent symptom in this affection is photophobia. The child dreads the light because of the sharp pain induced. What causes this pain? It is manifest that the phlyctenulæ disturb the sensory nerve endings in the epithelium of the cornea and that there is pain when the child opens and closes his eyes even in darkness, but this pain is not to be compared with that which arises when the eyeball is exposed to bright light. It is most likely that pain associated with photophobia is due to sudden cramp of the sphincter iridis. Cocain drops relieve it for a time; atropin drops for a longer time. This fact sustains the theory that the pain in phlyctenular keratitis is from cramp of the sphincter pupillæ. (For a full discussion of this subject see *Cramp of the pupil* in this section.)

The pupils in phlyctenular keratitis and conjunctivitis are very much contracted. There seems to be a defensive effort on the part of the eye to shutter the light. The pupillary response to light is as quick as lightning and while iritis is never present the patient evidently suffers from pain like in iritis.



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Persistent Pupillary Membrane.

Photography of the pupil. Kunz and Ohm (Graefe's *Arch. f. Ophthal.*, Vol. 89, p. 469) describe their apparatus for flash-light photography of the eye with or without binocular fixation. When they desire to photograph both eyes while only one eye is "fixing," the other eye is covered with a shutter which automatically exposes it at the moment the flash is fired. This determines the relative position of the eyes in this test and at the same time furnishes a photographic record of the size of the pupils. In dark eyes the pupils do not show distinctly but in light eyes they are clearly defined.

It occurs to the writer that we have in this method of testing, the only exact means of determining the size of the pupils in total darkness. In order to see the size of the patient's pupil it is necessary for us, by any other test, to admit enough light to allow our own eyes to see the pupil of the patient's eye. This amount of light vitiates the test for uttermost dilatability of the pupil. The photographic test with flash light in total darkness will record the pupils in the fractional part of a second (¼) and before the quickest response can act. It would be valuable and interesting to study photographic records of the pupils in series of cases of various diseases, local, general and cerebro-spinal, for thereby we might be able to fix upon definite diagnostic data of great significance. The instantaneous photographic record of the pupil in total darkness should afford valuable information as to the status of the cervical sympathetic nervous mechanism and the amplitude of its power.

Phthisis, Essential. Essential phthisis bulbi is one of the rarest ocular diseases. It was the author's good fortune to have seen a case in 1892. All the structures of the eyeball were enormously mumified so that the measurements of the ball were less than one-half the natural, and the cubical contents represented only about one-fourth of the natural. The cornea did not measure over 6 mm. in diameter and the pupil measured one mm. The eye was blind during the attack; the tension was greatly reduced; pain was a prominent symptom.

Phthisis, Unequal pupils as an early sign of. Tuechter (*Jour. A. M. A.*, Feb. 24, 1912) reported four cases of tuberculosis of the apex of the lung in which he noticed that one pupil was larger than the other and reacted more sluggishly to light. It is probable that these pupillary symptoms were caused by an involvement of the bronchial glands which caused them to swell and press upon the sympathetic nerve on the affected side.

Somogyi (*Wien. klin. Wochen.*, 1913, No. 28, p. 1185) reported the observation that in phthisical young people he had observed a change in the size of the pupil during respiration. The pupil dilated on deep inspiration and contracted with full expiration. He explained this by assuming that there was increased irritability of the vagus center. (For further reports on this subject see *Tuberculosis* in this section, also *Pneumonia.*)

Physiology, Bach's views. L. Bach (V. Graefe's *Archiv.*, Vol. LVII, No. 2) gives the results of systematic examination of the pupils in a great many cases. He thinks in general not enough attention is paid to the pupil considering its diagnostic importance. He states the size of the pupil is constantly changing, due to the antagonism of the two muscles of the iris, viz., the sphincter and the dilator.

Very varied influences from every part of the body induce reaction of these muscles. The sphincter reacts to light in proportion to its intensity, and it also contracts in convergence and frequently upon closing the lids. The dilator receives sensory and psychical stimuli almost constantly. The size of the pupil is dependent on: (1) Age, being small in the new born, large in youth and gradually becoming smaller and smaller as old age increases. (2) Sex, females, especially the more neurotic have larger pupils than males. (3) Refraction, the hypermetropic, especially the highly hypermetropic, eye is apt to have a small pupil; in emmetropia a wider pupil is the rule while in myopia the pupil is still larger. Exceptions are quite common for in anisometropia the hypermetropic eye may have a larger pupil than the myopic one; in a dim light myopes frequently have widely dilated pupils. (4) Visual acuity, loss of acuity is due to defects in the retina, optic nerve, chiasm, optic tract of external geniculate body, here the pupil is dilated. Loss of acuity or even blindness due to defect in the optic radiation or cortex does not affect the pupil but it may be larger on the side of the greater impairment. (5) Unequal development of the eyes—especially of the iris—is a very frequent cause of unequal pupils; the reactions may be normal; often there is one-sided development of the face and orbit. (6) A difference in size of pupil is frequently congenital.

The light reflex of the pupil starts in the retina and is not confined to the macula; it varies within certain limits with the intensity of the light and the amplitude of the contraction varies in different individuals. In the young, and especially among females, the reaction is quick and extensive. The pupils of intelligent persons often react more promptly than those of the dull. The view held by some that the direct and indirect light reflex are equal, that both pupils maintain the same size even with unequal illumination is wrong. To prove this the stronger light should be allowed to fall on one pupil for some time when a difference will usually be noted.

Haab's cortical reflex cannot be demonstrated in everyone and has not been shown as yet to have any practically diagnostic value.

On closing the eye the cornea tends to move up and out as a rule and the pupil contracts. This occurs in normal individuals although there are many exceptions.

Bach thinks that the convergence reaction is chiefly (if not exclusively) due to the impulse to convergence and not to accommodation. The promptness of the reaction and the amount of narrowing varies somewhat among different individuals. The amplitude of the narrowing depends of course on the size of the pupil to start with. In emmetropia and in hypermetropia the reaction is usually more prompt and more marked than in myopia.

Bach has published a book on the *Anatomy, Physiology and Pathology of the Pupil* (S. Karger, Berlin, 1908). A very good critical digest is found in the *Ophthalmic Review*, March, 1909. Bach states that according to Westphal the coarser fibres of the optic nerve, as demonstrateed by the microscope, are pupillomotor and not visual fibres. He found that these fibres receive their medullary sheath at an earlier period than the smaller or visual ones. Clincally the point is of some interest for the reason that the pupillomotor fibres suffer from the same causes and in the same degree as the visual fibres although sometimes the former may be more resistant and sometims less resistant than the latter.

At the chiasm the pupillary fibres undergo a semidecussation along with the visual and most authorities agree that they can be traced as far as the corpora quadrigemina, though some, among whom is Bach, state that they can be traced no farther and that they form fresh connections here. Bernheimer maintains that the fibres run an uninterrupted course to the third nerve nucleus and that the part of it known as the ''Edinger-Westphal,'' or small-celled median nucleus, is the part from which the fibres to the sphincter proceed. According to Bach, however, this collection of cells has probably nothing to do with the third nerve.

A curious question is whether or not the pupillary fibres undergo a second semi-decussation in the mid-brain. While the arguments advanced by Behr (*vide infra*) in favor of the view that they do so are not universally accepted the fact remains that in animals with total decussation at the chiasma there is direct but no consensual reaction of the pupil to light. There must therefore be a second total decussation of the pupillary fibres somewhere between the optic tract and the third nerve; otherwise it would be the pupil of the other side that would react. There is therefore an *a priori* probability that in animals with semi-decussation at the chiasm there is a second or return semi-decussation higher up. In the case of man Bach maintains that the direct reaction to light is greater than the consensual and if this is true it becomes a further argument to support the view that although part of the pupillomotor fibres cross at the chiasm they must recross higher up in order that the stimulus to the pupil on the same side should be greater than on the opposite side. That this greater reaction of the pupil to direct stimulation is a clinical fact is, as above stated, not generally admitted. Fuchs and Bumke grant that in some normal cases the direct and consensual reactions are unequal but only to a very slight extent. Bach states that in 80 per cent. of the cases examined by him the more strongly illuminated pupil was smaller by ¼ to ½ mm. than its fellow.

Besides the reflex action to light the pupil may contract in response to a central voluntary impulse such as when the eyes are focussed on a near object. This contraction is neither dependent on convergence nor on accommodation. Coincidentally the same voluntary central impulse excites at the same time the three sets of muscles—the interni, the sphincters and the ciliaries. In case one internus is paralyzed, however, there can be no convergence, yet the other two pairs of muscles will respond to the impulse, and the same obtains if the ciliary muscle is inactive as in myopia. Another phenomenon of analogous nature is the lid-closing contraction (see *Galassi-Gifford reaction*). In pupils normally responsive to light this reaction is difficult to observe but when the light reflex is absent, if the lids are tightly closed and then opened, the pupils may be observed to be contracted. They must therefore have contracted in response to a common impulse directed to the orbicularis oculi and the sphincter. The reaction may also be elicited reflexly by stimulation of the fifth nerve due to a foreign body on the cornea. The lid-closing reaction is consensual as well as direct and hence ordinarily no difference in the two pupils is observed, but if there is partial paralysis of the sphincter on one side the reaction may be plainly visible on the paralyzed side alone. The phenomenon is demonstrable during the effect of a weak solution of cocain. As to the nervous mechanism of dilatation the chief rôle is ordinarily assigned to the sympathetic but Bach, agreeing with Bumke, distinguishes between active dilatation due to stimulation of the dilator muscle which the sympathetic supplies and passive dilatation due to inhibition of the sphincter. The two types have been analyzed by special apparatus and photography and it has been found that dilatation due to stimulation of the sympathetic is characterized by a short, latent period, rapid in effect, and with a rapid return to the normal, whereas inhibition of the third nerve is followed by a slightly longer latent period with a slight primary dilatation, a rebound and then a more extensive and prolonged secondary dilatation. Bach maintains it is by the second, or inhibitory, method that sensory and psychical stimuli produce their effect and that spinal miosis is not due so much to paralysis of the sympathetic as to the loss of the stimuli that normally inhibit the sphincters.

Behr's views. Behr (Graefe's *Arch. f. Ophth.* V. 86, p. 468) from observations among twenty-six cases of monocular blindness presenting the so-called consensual pupillary reaction to light directed in the seeing eye, believes there is a central recrossing of the pupillomotor pathways. He states that the pupillary paths which start from the temporal halves of the two retinas, act chiefly on the pupillary nuclei of the opposite sides while those paths which start from the nasal halves of the retinæ act chiefly on the pupillary nuclei of the corresponding sides. The former enter the tracts uncrossed along with the visual fibres of the retina, while the latter (nasal side) cross to the other side via optic chiasm to the tracts of the opposite sides. It necessarily follows that both of these paths must recross centrally before passing into their nuclear origins.

The tests to prove this are as follows: When the light stimulus predominates on the temple half of the retina of the seeing eye the pupil of the amaurotic eye contracts, but when it falls chiefly on the nasal half of the retina the pupil of the amaurotic eye will dilate. The pupil of the seeing eye will behave exactly inversely to this, i. e., it contracts on more marked stimulation of its nasal half. This phenomenon may in some cases lead to interchangeable anisocoria. Repeating the tests and observations: Focusing a strong light on the nasal half of the seeing eye causes its pupil to contract sharply but in the pupil of the blind eye only a faint reaction is noted if any at all, and focusing a strong light on the temporal half of the retina of the seeing eye causes only a slight contraction of its pupil, but the pupil of the blind eye will contract sharply. These facts explain the dilatation of the pupil in the normal eye when there is a nasal defect in the visual field of the other eye.

Behr concludes further that assuming central recrossing of the pupillary paths and also a pupillomotor area representing both maculas in the cerebral cortex of each side it is possible consistently to explain all the disturbances of pupillary movement which are localized in the centripetal part of the reflex arc (see *Reflex pathways* in this section).

Von Hippel's views. Von Hippel (*Muench. Med. Wochens.,* April 19, 1904) has reviewed the extensive literature on this subject and states that diseases which affect the outer layers of the retina in spite of great visual disturbance leave the pupillary reflex intact while those situated in the entire thickness of the retina or in the inner layers cause pupillary disturbances. Schirmer concluded that the pupillary light reflex arc begins not in the rods and cones as does the visual tract but in the middle layers of the retina, i. e., in the layer of amakrine cells. This hypothesis has neither been proven or disproven. Von Hippel argues the following two important points against it: viz., that the size of the pupil is dependent upon the state of adaptation of the eye and that if the pupillary light reflex are began in the amakrine cells these cells would be closely related to the adaptation function; but the rods have been shown to have to do with this function. Again, the centre of the fovea from which the strongest pupillary reflex can be started is without amakrine cells. (See *Pupillomotor* in this section.)

The oculomotor nucleus according to the latest investigations consists of two principal collections of cells one on each side of the median line. There are two small-cell portions lying within the principal collection one on each side of the median line (Edinger-Westphal) and a single large-cell centre lying in the median line in advance of the centre. Von Hippel considers it proven that the small cell median nuclei are centres for the sphincter pupillæ; he does not declare, however, that they are the only centres.

Regarding the centripetal pupillary reflex fibre tract it has been found that a collection of fine medullated fibres leave the tract just in advance of the external geniculate body and run up and in toward the median line. As these fibres enter the white substance of the corpus quadrigeminum they radiate, a part of them going toward the sphincter nucleus under the aqueduct. These fibres come from the optic nerve but whether crossed or uncrossed, or both, is not known. Bernheimer concludes, however, that there is a partial crossing of these fibres in the chiasm similar to that of the visual fibres. It is probable that the connection between the two sphincter nuclei is by contact over the median line through ganglion-cell processes.

Bernheimer's scheme for the pupillary light reflex is as follows: In the retina and the optic nerve there are crossed and uncrossed pupillary fibres; the crossed group end in the small-cell median nucleus of the opposite side, the uncrossed end in the corresponding nucleus of the same side. They leave the optic tract at the geniculate body. The centrifugal fibres are uncrossed and proceed in the oculo-motor nerve from the sphincter centre through the ciliary ganglion to the sphincter iridis muscle. In the oculomotor nerve there are also uncrossed fibres from the single large-cell median group.

The question as to the nature of the ciliary ganglion is somewhat complicated by recent investigations. Schwalbe, Antonelli, Goldberg and Peschel consider this ganglion to be purely spinal and as subsidiary to the oculomotor. His, Remak, Phisalix and Gehuchten also consider it to be spinal but as subsidiary to the trigeminus. (See *Argyll-Robertson pupil, Cause of,* Dunn's theory.)

Retzius, Michel, Rauber, d'Ercline and Kolliker believe the ciliary ganglion to be purely sympathetic because it contains only multipolar cells; their fibres transmit always from the cells and never to them. Krause ascribes a double or mixed nature to the ganglion, and Hotzman believes it differs among different animals. The ciliary ganglion is probably an orbital center for pupillary reflex. (See *Neuroparalytic keratitis.*)

Physiology of the pupillary reflex. Levinsohn (Graefe's *Arch. f. Ophth.*, LIX, 2, p. 191) experimented to determine the cerebral center for the sphincter pupillæ and agrees with Bernheimer that it is situated in the small-celled median nucleus of Edinger-Westphal. He extirpated the ciliary ganglion, thus destroying the central neuron of the sphincter fibers, and found degenerative changes in the median nucleus on the operated side.

Bach and Meyer (*Ibid.*, 2, p. 332) experimenting on cats found that removal of the cerebral hemisphere does not affect the reaction of the pupils to light. If one hemisphere was removed the pain reflex could be demonstrated, but when both hemispheres were removed this reflex was lost. Removal of the cerebellum did not destroy the reaction of the pupil to light. A marked difference was noted between the behavior of the pupil in cats and rabbits when the fifth nerve was stimulated; in cats there was no pupillary contraction by this test while in rabbits there was marked contraction on the corresponding side. This contraction was not affected by section of the medulla in the neighborhood of the posterior corpora quadrigemina, but the contraction lessened when the superior cervical sympathetic ganglion was irritated.

Bach and Meyer from these findings conclude that there is an inhibitory center in the medulla for pupillary reflex in cats. The different findings in the same tests in rabbits are explained by the naturally sluggish reaction of the pupil in rabbits' eyes and the different anatomical arrangement of the visual pathways.

Pilocarpin, Mydriatic action of. Lilienfeld (*Centralbl. f. prak. Augenheilk.*, May, 1901) has noted that solutions of pilocarpin have occasionally been found to produce mydriasis where miosis was intended. The mydriatic effect of the drug in these instances has never been satisfactorily explained by the chemist or pharmacist. He advises that each solution should be tested as to its effect on the pupil before it is dispensed. He noted in a case that the drug produced miosis lasting an hour and a half, then the pupil became normal in size but was followed by mydriasis which was distinctly present thirty hours later. He attributes the late dilatation produced by the drug to faborin which he seems to believe forms as a decomposition product in pilocarpin solutions. This, if true, becomes valuable information as going to prove that some pilocarpin solutions may work a positive harm in an eye possessed of incipient glaucoma and would at once establish a contraindication for their use in glaucoma simplex.

Piltz psychic test in tabes. In some cases of tabes the pupils will contract independent of light while *thinking* of a bright light, and dilate regardless of darkness by thinking of the dark. Piltz's psychic test seems to be of no practical value.

Pneumonia, Anisocoria in. Burkoldt (*Inaug. Dissert,* Breslau, 1913) reported that he had found the pupils unequal in 23 out of 35 cases of unilateral pneumonia. The pupil on the side of the disease was dilated in 14 and contracted in 9 of his cases. This phenomenon is quite uncommon in pleurisy but was present in 58.3 per cent. of the cases of tuberculosis of one lung. Among seven cases the pupil was dilated, while among five it was contracted on the affected side. Anisocoria is most frequent in the second stage of the disease. Considering all cases of lung disease that he had observed the pupils were unequal in 65 out of 94 (69.1 per cent.). Thirty-nine cases presented dilatation and 26 contraction of the pupil. This observation has been corroborated by internists in Cincinnati. (See *Tuberculosis* in this section, also *Phthisis pulmonalis*).

Poisons that dilate the pupil, List of common.

1. Hydrocyanic (prussic) acid (oil of bitter almonds, cyanite of potash).
2. Aconite.
3. Belladonna (atropin).
4. Cannabis indica (Indian hemp).
5. Chloral (at first contracted).
6. Chloroform.
7. Cocain.
8. Conium (hemlock).
9. Digitalis (fox glove).
10. Ergot.
11. Gelsemium (yellow jasmine).
12. Hyoscyamus (henbane).
13. Nitrite of amyl and other nitrites.
14. Nitroglycerine.
15. Sanguinaria (blood root).
16. Stramonium (Jamestown weed).
17. Turpentine.
18. Scopolamin.
19. Wood alcohol and quinine that produce blindness.

Poisons that contract the pupil in lethal doses.

1. Carbolic acid (creosote).
2. Alcohol in lethal doses.
3. Calabar bean (physostigma).
4. Chloral (at first).
5. Jaborandi (pilocarpin).
6. Opium (and its salts, morphine, codein, etc.).

Poisoning, Carbon-monoxide (illuminating-gas). Patients overcome with the fumes of gas present many of the general symptoms seen in multiple neuritis. The pupils are widely dilated and fixed, entirely so in the unconscious stage and less marked as consciousness returns. Blindness and consequent mydriasis has been reported by Sibelius in a boy of twenty who subsequently developed dementia and epilepsy and died after three months. A post-mortem revealed the blindness to be due to bilateral softening of the visual cortex in the occipital lobes.

Poisoning, Dilatation in chlorodyne. Powell (*Ind. Med. Gaz.,* August, 1902) stated that among four cases of fatal chlorodyne poisoning that came under his notice there were widely dilated pupils noted in each. The chlorodyne solutions he examined differed greatly as regards the dilute hydrocyanic acid content. One sample contained 25 minims, another 55 minims to the ounce. The morphin content was four grains to the ounce. Powell explained the dilatation of the pupils by assuming that the mydriatic effect of the hydrocyanic acid in overwhelming doses would easily overpower the tendency to morphin miosis possessed by the drug.

Poisoning, Lead. Workers in lead are subject to a peculiar form of multiple neuritis affecting the nerves supplying particularly the extensor muscles of the upper extremities. Occasionally the poisonous effects of lead are exerted on the cerebrum and we then have exhibited symptoms referable to the brain and cranial nerves. Again the cells of the anterior horns of the spinal cord, including the anterior roots of the spinal nerves, may show degenerative lesions. The pathology is mostly a study in acute degeneration of nerve cells, nerve centers, nerve tracts and neuraxons, expressed more violently in certain motor tracts than in others and varying greatly in different subjects and that, too, in varying intensities, so that we may observe all kinds of interesting symptoms from an isolated palsy to a profound encephalopathy including delirium, coma, epileptoid seizures, hemiplegia and even death.

Optic neuritis and blindness are common in the cerebral cases and in them we find more or less dilated and fixed pupils usually in proportion with the degree of amblyopia present. Loss of light reflex is also of frequent occurrence in the brain cases. Miosis is of very rare occurrence. In many cases the optic nerves and retina show slight if any involvement, as noted by deSchweinitz, and among them the pupils act and react normally. (See *Multiple neuritis* in this section.)

Poisoning, Sulfonal and trional. The effect of lethal doses of sulfonal, trional and other coal-tar derivatives of their class is very similar to that produced by the fumes of carbon-monoxide (illuminating-gas). The pupils are found to be dilated, one usually more so than the other. These drugs in overwhelming doses have been known to produce interstitial neuritis with degeneration of the nerve trunks and peripheral endings as proven by post mortem examination.

Polioencephalitis, Normal acting pupils in acute hemorrhagic superior. In this rare disease, first reported by Wernicke, (*Lehrbuch d. Gehirnk,* 1881, Vol. XLVII, p. 229) there are multiple hemorrhages in the dorsal portion of the third ventricle and the region of the aqueduct of Sylvius, including especially the nuclei of the ocular nerves. The prominent symptoms are marked and rapid paralysis of the ocular muscles, a staggering gait and a mental condition similar to delirium tremens. The pupils are usually not involved. The location of the centers for the sphincter pupillæ in the anterior colliculi of the corpora quadrigemina, a location just outside the zone of involvement, permits it to escape in a classical case of this disease.

Among twenty undoubted cases of this disease studied by Wilbrand and Saenger (*Neurolog. des Aug.*, Bd. I, Abt. 1, p. 270) the pupils in some cases were normal to light reaction and completely immobile in others, so that they do not conform to any one rule of behavior. The presence of normal acting pupils to light in the symptom-complex of this disease is undoubtedly suggestive and of distinct diagnostic value.

Polycoria, Congenital. The eye may present two or more pupillary openings through the iris. Where the anomaly exists the opening intended for the normal pupil is never round but is more or less pear-shaped and the accessory pupil is placed at the peripheral portion of the iris in the direction of the lesser curve of the elliptically-shaped pupil. This elongation of the central pupil in one direction usually occurs downwards or obliquely downwards, and the supernumerary pupil is separated from the main pupil by a bridge of iris tissue. This invariable arrangement in cases of "discoria" suggests at once the true cause, viz., that the condition is the expression on the part of the embryonal tissue of the iris in the process of iris-formation to frustrate the formation of a coloboma. If the "bridge" had not grown across the gap to produce a double pupil there would have occurred a congenital coloboma. This condition then is almost invariably found in the pathway of the optic cleft. Examination of the central pupil which is pear-shaped shows evidence of a broken or unclosed sphincter pupillæ, as well as a fading out of the markings of the "lesser circle" of the iris. There is no evidence whatever of a sphincter being present in the accessory pupil. The structure of the bridge shows evidence of attenuation and feebly expressed crypts. The pigment layer of the posterior surface of the iris will rarely be present where the bridge exists. Thus we can infer that the dehiscence or cleft in the iris is complete in-so-far as the ectodermic tissue forming the retinal pigment layer of the iris is concerned but is only partial as regards the mesodermic tissue forming the substantia propria of the iris.

There are other kinds of double or multiple pupil to consider. One form is due to persistent pupillary membrane which runs in a pathway across the round central pupil areas, one often being larger than the other and neither being round. Such an anomaly tells at once that the condition is not a frustrated coloboma but is a residue of the pupillary membrane bisecting the round pupil. Indeed it is possible for the round pupil to be subdivided into several or many "pupils" by a net-like arrangement of persistent pupillary fibers. In all these conditions it is easy to demonstrate that the sphincter iridis is complete as well as the rest of the iris tissue.

Another form of polycoria is due to the same cause that produces in other cases atypical or eccentric coloboma as explained (see *Coloboma* in this section), that is, by the result of retardation or hindrance of the ingrowing edge of the secondary optic vesicle, in which, after a time, and before the embryonal cells have ceased growing, there occurs a lateral growth of cells to form bridges where a coloboma would otherwise have existed.

In such cases we may find the iris curiously riddled with congenital holes which pursue no definite arrangement as to location, thus proving at once that they are not due to failure of closure of the optic cleft. Where this form of polycoria exists the pigment layer of the iris is scant or wanting entirely, while the pattern of the iris is entirely fashioned by the mesodermic layers derived from the anterior vascular sheath of the lens.

Polycoria in glaucoma. Benson (*Trans. Royal Acad. of Med. of Ireland, Sec. of Path.*, March, 1900) showed a case in which in addition to the normal pupil in the right there were eight other openings in the iris; in the left iris one extra opening. The accessory pupils were mostly slit-like through which the fundus could be illuminated.

Pons and medulla, Diseases of the. Hirsch (*Zeitsch. f. Augenh.*, April, 1903) collected eighty cases of pure, mostly unilateral, diseases of the pons and reports widely dilated pupils in 25 per cent. of them. As to the pupillary inactivity in these cases the question arises whether it should be ascribed to optic neuritis and blindness. Since, however, 15 per cent. of the cases presenting mydriasis presented no lesion of the fundus he is inclined to believe in a connection between the pupil reflex and the medulla. Bach and Mayer claim there is a reflex inhibitory center in the medulla through a descending path in the fillet and an ascending path in the posterior longitudinal fibers. Involvement of this center would occasion the widely dilated and fixed pupils.

Postmortem reaction of the pupil in rabbits after decapitation. Ruge (Graefe's *Arch.*, LIV, p. 483) reports that even after complete division of the medulla oblongata there was perceptible pupillary reaction in the eyes of rabbits and cats. This finding fails to substantiate Bach's idea of the spinal location of the center for pupillary reflex. (See *Death* in this section.)

Psychic reaction. Westphal (*Deutsche. med. Wochenschr.*, 1912, No. 38) reported three interesting cases demonstrating the psychic reaction of the pupil.

I. A woman with migraine presented dilated and immobile pupils at the menopause. The condition resembled third nerve palsy in which, however, only the pupillary branch was involved. A similar pupillary condition which alternates with the normal is met with in katatonia. The influence of psychic and vasomotor disturbances undoubtedly bears on these cases.

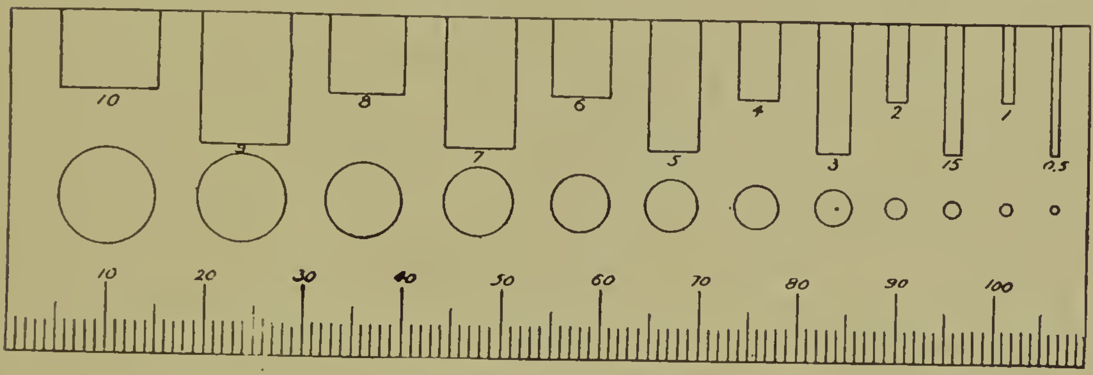
II. A patient with no signs of syphilis, tabes or paresis presented paradoxical light reaction. There was dilatation instead of contraction to light. This dilatation, however, had a preceding fugitive contraction which was detected with the loupe and which soon gave way to the dilatation. It is most likely that all paradoxical pupils present a momentary contraction which escapes detection when light is thrown in the eye and that owing to psychic influence the pupil dilates instead of contracts in the light.

III. A patient with maniacal excitement showed marked reaction of the pupil to light and this contraction remained in a spastic condition and would not respond or dilate until the room was darkened.

Psychic states, The effect of. Conscious states, especially of a psychic nature like fright, anger, terror, etc., frantic states of the mind brought about by what we see, smell, taste, touch or hear are associated with equal dilatation of the pupils (Bumpke's pupils). The converse of these are the unconscious states such as slumber, hebetude, dream states, narcosis, general anesthesia, etc., which are associated with equal contraction of the pupils.

In the former, upon withdrawal of the psychic influence producing terror of mind, the pupils resume the normal state, while in the latter on awaking to the appreciation of orientation the pupils return to the normal standard. These facts enable the diagnostician to appreciate the mental equipoise of the patient by observing the pupils. (See *Subconscious states* in this section.)

Psychoses, Organic brain lesions. Marked pupillary abnormalities exist in all cases of organic cortical lesions of the brain. It is not uncommon to find one pupil dilated in these cases and more or less contracted pupils are likewise often observed. Loss of pupil reaction to both light and accommodation is common among the insane.



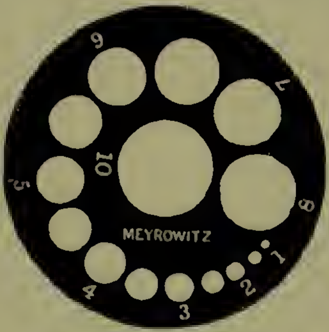
Hirschberg Pupillometer.

Pupillometer. The pupil lies in the bottom of the anterior chamber. The cornea and aqueous together act as a magnifying medium and hence the pupil always appears larger than it really is. Moreover it seems to lie closer to the cornea than is the fact owing to the refraction of the transparent aqueous. Nevertheless for practical purposes the pupil width can be estimated by actually measuring its diameter with a millimeter-scale held closely to the cornea, or by comparing its size with the standard pupillometers and selecting and noting the size of the perforation in the instrument that corresponds with that of the pupil under observation.

The Morton ophthalmoscope has a pupillometer scale similar to that shown in the accompanying illustration attached to the rotating disk. This is a handy contrivance and answers for all practical purposes. Pupillometers have been devised by Wells, Hirschberg, Landolt, Schirmer and others. (See illustration showing Hirschberg's.)

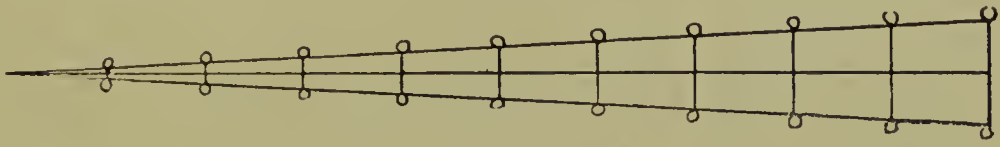
In medico-legal cases it is sometimes necessary to state under oath the size of the pupil. The expert should use a pupillometer and note the exact size. In other cases for record and future comparison the pupillometer should be used.

Pupil, Measurement of exact size of the. Cooke, of Seattle (*Ann. Ophthal.*, Vol. XIII, No. 4, p. 768) calls attention to the fact that the size of the pupil as estimated with the ordinary millimeter scale or pupillometer is erroneous for the reason that the cornea and aqueous magnify it. In order to ascertain the real size of the pupil he has devised a method which is novel and ingenious although open to the objection that it is a subjective test. His method is based on the following experiment: Two series of stenopaic openings are made at equal intervals along two diverging lines intersecting at one end and being 10 mm. apart at the other end as shown in the diagram. This card is held before the eye at a distance of approximately 13 mm. from the cornea (estimated) and the patient directs his gaze through these double holes starting with the holes closest together (1 mm.) and moving the card along the series of holes that are wider apart (every 10 mm. space). The patient when looking through the first pair of holes will see two bright circular fields of light which overlap. The overlapping parts are brighter on account of the double amount of light that illuminates the corresponding overlapping images on the retina (see fig.) (a) and as the next pair of holes are placed before the pupil the circular fields of light are less overlapped (b) and with the third pair of holes in front of the pupil this overlapping of the bright fields is still less (c). If the test is progressively continued these light circular fields will

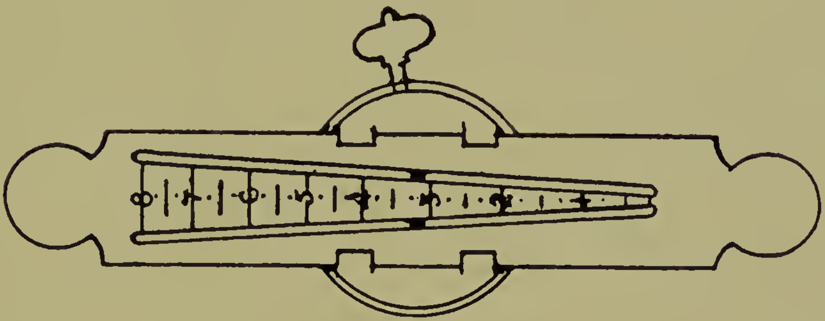


Circular Pupillometer.

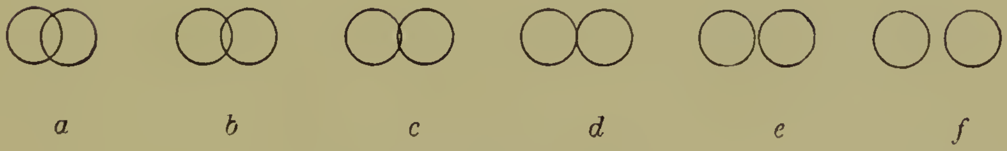
be seen to touch at their peripheries (d) and when the next pair of holes is employed they will be seen separated (e) and with still the next they will be farther separated (f) etc. The pair of holes in this test which produces the light fields whose margins are just tangent to each other will give us the exact or true size of the pupil if we measure the distance these same holes are apart on the card. By this test the pupil fields are not sharply defined in outline but



Cooke's Pupil Measurement.



Cooke's Koreometer.



Cooke's Circular Fields.

the difference between the point where it is possible to say the fields overlap and the point where it is possible to say they do not touch is not greater than one-fourth mm. The method therefore appears sufficiently accurate for clinical purposes. In the test thus far described the observation is made with one eye, the other being closed or kept in darkness. If, now, the second eye is opened and exposed to the bright light the circles of light observed with the eye behind the stenopaic holes are seen to draw apart and it will be necessary to select a pair of holes nearer together in order to have the circles approach and become tangent again. This is the consensual-contraction size of the pupil. The difference between the direct measure and the consensual measure of the pupil is about 1 mm. in the normal eye in ordinary daylight. (See *Subjective examination, Pupillary reflex.*)

Using this principle Cooke has devised an instrument for measuring the real size of the pupil which he calls a koreometer. The illustration indicates its appearance. He uses a narrow strip of metal which tapers from one to ten mm. in width. This will give measurements to one-tenth mm., if required. The metal strip is made to glide across a trial frame disk in which is an ordinary stenopaic slit and with this instrument one can, even in the case of patients of low intelligence, quickly and accurately measure the exact size of the pupil. The strip of metal referred to is constructed to correct the apparent size and give the real size, for example, a pupil that measures 4.44 mm., as seen through the cornea and aqueous, is indicated to measure 4 mm., and one that measures 8.91 mm. is indicated to measure 8 mm., its true size. This is in conformity with the following scale of corrections computed from Tscherning's formula for calculating the width of the pupil as seen through the cornea and aqueous.

9.01 mm. for an 8 mm. pupil.
7.88 mm. for a 7 mm. pupil.
6.76 mm. for a 6 mm. pupil.
5.6 mm. for a 5 mm. pupil.
4.507 mm. for a 4 mm. pupil.
3.3 mm. for a 3.3 mm. pupil.
2.2 mm. for a 2 mm. pupil.

Duane (Knapp's *Archives of Ophthal.*, Vol. XLIV, No. 5, p. 483) employs the principle of Priestley Smith's keratometer in measuring the diameter of the pupil. "A millimeter scale placed in contact with a + 2.75D lens is held in front of the pupil and the number of mm. that the latter subtends when seen through the glass is read off by the observer, who should be stationed not far from the focal point of the lens (36 cm.). A very accurate measurement will thus be obtained even when the scale is not held very close to the pupil."

Contino (*La. Clin. Oculist.*, Nov., 1911) mentions the difficulties encountered in estimating the exact size of the pupil and refers to the inadequate means proposed by many to ascertain this measurement. He has devised a method for which he claims absolute accuracy. His apparatus consists of a horizontal microscope which is fitted with a special eyepiece and armed with a micrometer glass scale. He eliminates the troublesome shadow that falls on the eye by employing a strong prism. Having found the apparent size of the pupil as indicated by the instrument, he then calculates the real size by using a table of mathematics.

Pupillometer, Binocular. Ohm (*Centralbl. f. Augenh.,* Aug., 1906, p. 129) states that comparison of both pupils at the same time is very important in the study of numerous physiologic and pathologic questions. Hence he devised his binocular pupillometer with which, by means of a system of prisms, the images of both pupils are brought side by side and may be measured with great accuracy.

Bordier and Nogier (*Rév. géneral d'ophtalm.,* Vol. XXVI, p. 529) describe an improvement on Houdin's instrument which had been modified by Badal. The advantage consists in the possibility of measuring the diameter of the pupil rapidly and in any light. With regard to its construction the reader should consult the original article.

Pupil scale, Isochromatic. Krusius, of Marburg (*Trans. 11th Internat. Ophth. Cong.*) demonstrated his pupillometer consisting of a red ground-glass disk with graduated holes provided in an aluminum shutter, allowing the pupil to be measured by reflected or transmitted light.

The scale is always of the same color as the pupil, thus avoiding the common source of error.

Pupillomotor fibers in the retina. Hess (*Arch. f. Augen.,* Sept., 1907) states that two facts render the ordinary clinical method of testing the pupil reaction valueless for the purpose of deciding the location of pupillomotoric fibers in the retina. One is that on whatever point in the retina light is focussed the amount of light which is diffused and so reaches other parts of the retina, is always considerable. The other is that with lateral illumination the amount of light which passes through the iris and even through the sclera, is perceptible and may be sufficient to cause a contraction of the pupil.

Hess devised a method of examination which consists in focussing the light which enters the pupil at different points in the circumference of a circle which has the macula as its centre and the distance between the fovea centralis and the centre of the blind spot as its radius. He states that when a beam of light is directed on the blind spot the diffused or reflected light and not the direct light on the nerve head is what excites the sensation of light and causes pupillary contraction. When the same pencil of light is directed on any point of the retina at a distance from the macula equal to that of the blind spot from the macula the amount of diffused light will be equal to what it was when the blind spot was illuminated but the direct rays will be brought to bear upon the rods and cones at the retinal point on which they are focussed. We would naturally expect greater and prompter contraction of the pupil when this retinal area was illuminated than when the blind spot which contains no pupillomotor fibers was illuminated.

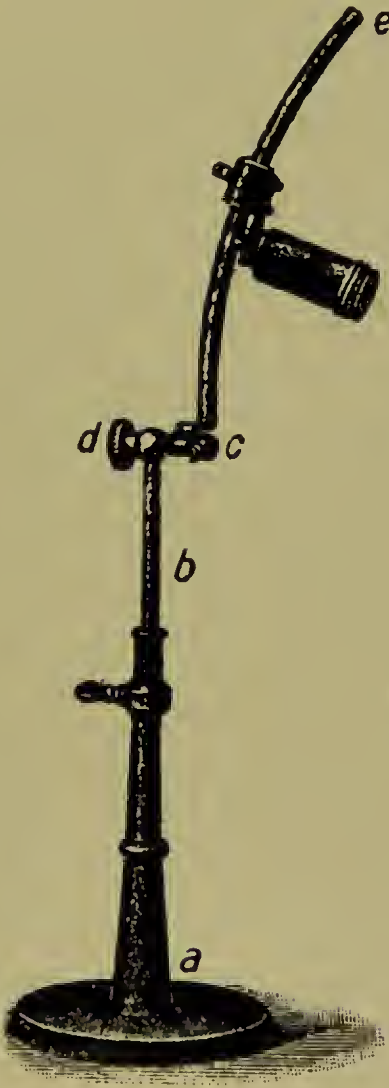
The result on the pupil of directing the light on the blind spot is exactly the same as that of directing it on any retinal point in the same circumference having the macula lutea as the center. These experiments go to disprove the theory that the parts of the retina outside the circumference of this circle have any pupillomotor fibers at all, i. e., outside a circle of 3 mm. radius from the macula.

These facts throw doubt on the value of the clinical observations hitherto recorded on the subject of the hemianopic pupillary reaction.

Hess also raises the question as to the exact location in the retina where the impulse to pupillary reaction is first incited. In most birds owing to the presence of red and yellow oil globules between the inner and outer limbs of the cones the spectrum is considerably shortened at the blue end as compared with what is visible to us. In the retina of night birds, such as owls, these oil globules do not exist. Now if the apparatus for receiving pupillomotor impulses is located in the inner granular layer, as some have maintained, there would be no difference in the action of different colors in exciting the pupillary reaction. But Hess's experiments showed that with day birds (pigeons, hens, jackdaws) the greatest reaction is obtained with orange and yellow light, blue being almost powerless to excite any reaction. Whereas with night birds (owls) the reaction is greatest with green light; as the long-wave end of the spectrum is approached the reaction lessens rapidly, towards the short-wave (blue) end the reaction lessens much more more gradually and similarly to that noted in the normal condition of the human eye when adapted for dark. These facts tend to show that the reason for the different behavior of the pupil in day birds lies in the existence of the above-mentioned yellow and red oil globules and the conclusion is therefore reached that the recipient pupillomotor apparatus is located in the outer limbs of the cones. (See *Physiology of the pupil, von Hippel's views,* also *Threshold value* in this section.)

Pupillomotor area of the retina. Hess (*Arch. of Ophth.,* Vol. XXXVIII, No. 2) again investigating the question of the location of the pupillomotor fibers of the retina mentions that Heddaeus more than twenty-five years ago suggested that only a small area of the retina contained the pupillomotor fibers but decisive experiments were lacking to prove his contention. Hess devised an apparatus which he calls a "pupil perimeter" (see figure) and which he describes as follows:

"On a firm stand (a) was fastened a rod movable up and down (b), to which was attached a metal quadrant (c, e), revolvable about its axis (c, d). This quadrant had a radius of 35 cm. and had attached to it at right angles a cylinder impervious to light (f) containing an electric lamp. The anterior surface of the cylinder was formed of ground glass in front of which was placed a diaphragm, by means of which the diameter of the irradiating surface could be varied at will from 0 to 22 mm., and the light strength could be still further varied by means of a rheostat, or by the interposition of more ground-glass plates. At the zero point of the quadrant (c) a little electric lamp was placed in a capsule provided with a minute



Hess' Pupil Perimeter.

opening the light strength of which was to be regulated so that the observer could just perceive the openings as a minute, weakly lighted point in the condition of adaptation in which he was at the time.

"By moving the lamp (f) on the quadrant (e, e), and by turning the quadrant about its axis (e, d), places on the retina equally distant from the centre could be investigated in the above-mentioned manner, at such eccentricity and with such size and strength of the irradiating light as might be desired."

It is impossible to produce a spot of light in the bottom of the eye without there being luminous circles which extend quite a distance beyond the illuminated spot. For instance, with a source of light at a distance of one meter and of a diameter of one centimeter, the retinal image has a diameter of only 0.15 mm. or 1/12 of the normal diameter of the optic disk and thus covering only about 1/144 of its service. Under such conditions the circum-papillary brightness of the diffused light may be clearly seen.

If, after the pupil is noted in this test the source of light be made brighter the pupil will contract still farther, even when the focus on the optic nerve head was not increased in size. This goes to prove that the circles of diffused light will stimulate the pupil to contract even when the image of the light lies wholly on the blind spot. By means of his pupil perimeter Hess was able to prove that the pupil did not contract when the image of the light was focused on the periphery of the retina, but that as soon as the focus was permitted to fall in the region of the fovea a distinct contraction of the pupil was produced.

He was able further to prove to his satisfaction that the part of the retina immediately adjoining the optic disk was not supplied with pupillary contracting fibers. In the area which is, according to his experiments, supplied by pupillomotor fibers the pupil did not respond any more actively when the light was focused in one part of the sensitive area than any other part. The area which contains the pupillomotor fibers, according to his experiments, embraces a circular zone with a diameter of less than 6 mm. with the fovea at the center. He maintains that "if pupillomotor areas exist outside of the center of the retina they probably lie more or less concentrically about the point of direct vision, and we may therefore conclude that the pupillomotor area of the retina has at most a radius of 3 mm. and may be even smaller. (See *Pupilloscope* in this section.)

Pupillomotor fibers in the retina, optic nerve and optic tract. Spiller (Posey and Spiller, *The Eye and Nervous System*, p. 1) states that while authorities are not all agreed that there exist differentiated nerve fibers in the retina, optic nerve and tract which are concerned in conveying the light stimulus to certain brain centers and incite a return impulse to the sphincter pupillæ, there is a very strong presumption, commonly conceded, that such a mechanism must really exist.

Von Gudden, Von Bechterew and Reichardt maintain that the thick fibers they have demonstrated in the optic nerve and optic tract are not concerned in the act of vision: they convey centripetal impulses to the pupillary reflex center. Massaut has found degenerated coarse fibers in the optic nerve after extirpating the iris in rabbits and maintains they were the pupillomotor fibers that had degenerated as a consequence of amputation of the iris. There is some doubt of the truth of this observation for it is a logical deduction that in such instances, there being no destruction of the recipient or centripetal-conducting fibers in the retina, the impulse to light stimulus was conveyed to the pupillary center and that no such atrophy or degeneration could exist, for it is well known that degeneration only results in nerve fibers from loss of function and that therefore in the instance cited such function (conveyance of stimulation up to the brain center and down to the amputated end) was not abolished.

If it can be proven that atrophy of the visual fibers of the optic nerve may occur to produce total blindness and still leave the pupillary fibers of the retina unaffected, and if in such instance it can be possible to produce pupillary reaction through light stimulus directed in such an eye, we would have the strongest circumstantial proof that independent "pupillary reflex fibers" do exist. Reichardt and Piltz as cited below claim this has been proven. There are other proofs presented to satisfy the claims that independent pupillary reflex fibers exist in the retina and optic nerve, e. g., in compression of the optic nerve the visual function is affected before the pupil reflex shows impairment, which goes to prove that the pupil reflex fibers are more resistant than the visual fibers in the optic nerve. This observation seems sustained by the fact reported by Westphal, viz., that the coarse fibers (pupillary reflex fibers) of the optic nerve receive their medullary sheaths sooner than the fine ones (visual nerve fibers) and, moreover, that when an acute optic nerve inflammation recedes it is a clinical observation that the pupil reaction begins to return somewhat in advance of the return of vision.

Piltz, who has written extensively on this subject, described a case in which there was positive pupil reaction for nine years in a case of total blindness, and others have noticed pupil reaction better in the eye that was nearly blind than in the fellow eye that still possessed good vision.

Reichardt has observed pupil reaction after complete blindness had set in. The converse has likewise been observed and reported, and this any one of experience will concede, viz., that the pupil may be fixed in spite of the presence of perfectly normal vision and accommodation. We see this in tabes and allied affections and this observation may be argued to mean that there is in such cases a lesion of the pupillary light reflex arc which in no way affects the visual arc.

The coarse, or pupillomotor, fibers are found scattered among the fine or visual fibers in the optic nerve and in the main pursue the same course as far as the external geniculate body where they separate. It is believed that the fibers concerned in pupil responses that originate in the temple side of the retina do not cross over but remain on the same side like the visual fibers from the same locality, but that those on the nasal side cross over in the chiasm. Support to this belief is found in the fact that in clearly-cut bitemporal hemianopsia, as occasionally found in cases of pituitary disease, careful tests with a beam of light directed against the nasal wall of the retina does not meet with pupil response, whereas if directed against the temple wall of the retina, prompt reaction results. (See *Wernicke's reaction* in this section.)

After reaching the corpora quadrigemina it is supposed the pupillary fibers pass on to the anterior colliculus and to communicate with the stratum zonale of the pulvinar of the ganglion habenulæ, but it is not known if this is true, nor indeed if there exists any connection with the origin of the motor oculi although such a connection is highly probable. Much seems required to clear up this interesting problem and when the pathway is finally discovered and proven, we may then be able to interpret much of the anomalous behavior of the pupil in certain abnormal brain states.

Pupilloscope, Hess' differential. Hess (*Archiv. f. Aug.*, 80, p. 213) uses an instrument which he calls his differential pupilloscope with which he can find the effect of the smallest differences of light intensities which alter the size of the pupil. (See *Pupillomotor fibers of the retina* in this section.)

The threshold of excitation of the pupil by light influence cannot be determined because of the darkness which does not permit the pupil to be seen, but the differential threshold of sensibility of pupil response to light can be studied with his instrument. The reaction of the pupil to light and the perception to light are in close connection but not identical. He reaffirmed his discovery that only a small circumfoveal area of the retina contains pupillomotor fibers and that motor excitability rapidly decreases from the fovea toward the periphery. Furthermore that the pupil reacted to the light thrown on the periphery because the foveal area was excited by reflection and diffusion of light within the confines of the vitreous chamber. The relation between vision and pupil action is not maintained, for the pupilloscope demonstrated that when the vision was reduced to counting fingers in cases of opacities of the dioptric media the pupil may respond normally. The clinical value of this observation finds its greatest application in cases of cataract, for we may feel assured that if there is normal pupillary response there is great probability that the foveal region is unaffected.

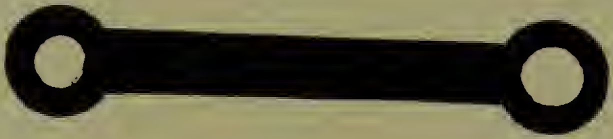
Hess thinks that his pupilloscope is the only positive means yet discovered for testing the visual possibilities of the fovea in cases of cataract. In this connection Lt. Col. Henry Smith of India relies solely upon the ready response of the pupil to light in determining the operability of an eye possessed of a cataract. Smith also maintains that there is a direct and intimate connection between the response of the pupil and visual acuity and regards the test to be infallible.

Hess found with his pupilloscope that in normal youthful eyes there was a quick and ready response to the smallest differences of intensities of light, while in the aged the response was tardy, which latter he attributes to the diminished elasticity of the tissue of the iris in the aged. He refers to the value of his pupillometer test in detecting oncoming iridoplegia long before the actual onset of the disease in cases of tabes and paresis.

In a case of total blindness in one eye since childhood where a normal fundus existed he found with his pupilloscope a normal motor differential sensibility, thus proving that in a perfectly blind eye the pupillary reaction may be the same as in the normal eye.

Pupil stop in skiascopy. E. Jackson (*Ophthal. Rec.*, Dec., 1905) observes that accurate skiascopy depends upon obtaining a small and definite light area on the retina. The dilated pupil, which is present whenever a cycloplegic has been used, permits, as the point of reversal of the shadow is approached, a confusing play of shadows due to the central and the pupillary zone of aberration influencing the reflection rays differently, thus giving rise to "scissors movement" and the broken-up appearance of irregular astigmatism.

Since the irregularities of refraction are much greater in the periphery of the pupil than near the center, and since, too, the non-dilated pupil cuts off much of the spherical aberration (in fact during the act of convergence and accommodation the pupil is so contracted that the aberration referred to is rendered negligible) it is desirable to estimate the refraction during complete suspension of accommodation as effected with a cycloplegic and at the same time do this through a pupil space not enlarged, if that is possible. Jackson states, "The smaller the pupil the smaller and more definite is the light area under observation and the greater the possibility of accuracy with skiascopy." In advanced presbyopes it is possible to estimate the refraction accurately through the pupil undilated with a mydriatic, for here the accommodation rôle is lost. In younger individuals who possess active and powerful ciliary muscles a cycloplegic is necessary in order to ascertain the exact anomaly but the dilated pupil always accompanies cycloplegia and in order to shutter the annoying aberration present in these cases when the shadow test is being applied, Jackson recommends his "pupil-stop" shown in the accompanying illustration. The circular openings in the bar of metal shown in the cut are five and six mm. in diameter respectively, for the most satisfactory skiascopy work can be done through a pupil of either of these sizes. The ring around each opening in the pupil stop is only wide enough to cover the periphery of the dilated pupil (10 mm.).

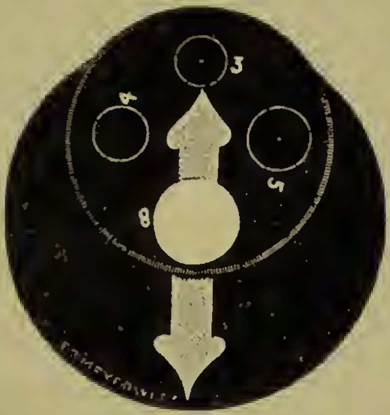


Jackson's Pupil Stop.

In using this device Jackson recommends that it be held by the surgeon before the patient's pupil with his left hand steadied against the patient's brow or temple while the mirror is held before his own eye with his right hand. The stop is held quite close to the patient's eye under observation and should correspond to the exact center of the pupil. This latter position is secured by observing before hand where the corneal reflex is placed in relation to the center of the pupil, and the same relative position of the corneal reflex is maintained through the aperture. "In a large proportion of cases it affords no material help but in some cases it is of considerable value in promoting accuracy."

Pupil stop as an aid in refraction work. A. B. Mason (*Ophthal.*

Rec., Jan., 1915) acting upon the advice given by Thorington that in the shadow test it is desirable to watch for the movement of the illumination "through a 4 or 5 mm. area at the apex of the cornea in order to estimate the refraction properly," has devised the pupillary disk shown in the accompanying cut. This disk is used to eliminate spherical aberration which confounds the test after the pupils are dilated with the cycloplegic. The method recommended is to measure the pupil before the cycloplegic is used and note the size of the aperture that will correspond. Then proceed with the cycloplegic drops and after paralysis of accommodation is complete and the pupil is widely dilated, to insert the pupillary disk in the trial frame using the aperture which corresponds to the natural size of the pupil as determined beforehand. The shadow test is worked through the aperture and the correcting lenses applied.



A. B. Mason's Pupillary Disk.

Mason's argument in brief is that since the pupil having a diameter of 4 mm. has an area of 12.566 sq. mm., and the same dilated pupil of 8 mm. has an area of 50,265 sq. mm., there is an area of 37.699 (the difference between these areas) which, being in preponderance and exposing a ring of red shine corresponding to the parts of the lens that possesses the power of aberrating the rays there is, as a consequence in this test, a confusion of shadows elicited which impairs the accuracy of the test and tends to yield incorrect results.

His previous pupillary disk mentioned in *Ophthalmic Record*, Dec., 1912, is recalled as being too thick and clumsy. The one shown herein is faultless and does not interfere with the placement of lenses, both spheric and cylindric if inserted in the middle clip of the trial frame with the revolving-disk-side back. The revolving disk has four apertures, 3, 4, 5 and 8 mm. respectively and there is provided an axis pointer which assists in the test. Mason refracted 100 cases with and without the use of this pupil stop and reports the following results:

Same vision with same correction 10 cases.
Same vision with different correction 29 cases.
Better vision with same correction 32 cases.
Better vision with different correction 29 cases.

Thus, he claims either better vision or better lens correction was found in 90 per cent. of these cases by the aid of this instrument and a different correction was found in over 50 per cent. of the cases. He mentions the value of the disk in compelling the patient to look straight through the center of the correcting lenses and not be peering askance and ducking as they are wont to do when this disk is not used. He concludes by stating he believes it is just as important to eliminate spherical aberration through the dilated pupil as it is to paralyze the muscle of accommodation in our refraction work.

Quinine blindness. deSchweinitz (Knapp's *Archiv.,* March, 1910, p. 101) reports a case of quinine blindness in a man who presented grayish-green atrophy of the optic disks and a concentric contraction of the visual fields to within 10 and 20 degrees of the center. The pupils in this case were normal in reaction. This finding tends to support Hess' theory that the pupillomotor fibers in the retina exist only in a small area (3° radius) in the macular region.

Quinine in large doses causes in some instances an acute primary atrophy of the optic nerve. Associated with this is more or less profound amblyopia usually involving the center of the visual field and expressed as a central scotoma. In one instance the writer of this section discovered a paracentral or ring scotoma. The pupils are usually dilated somewhat and they react feebly to the light.

Rabies, Pathognomonic contraction. Coakley, of Chicago (*Trans. Ophthal. Sec., N. Y. Acad. Med.,* April 15, 1907, Knapp's *Archiv.,* Vol. XXXVI, No. 5, p. 725) examined one hundred and fourteen rabid dogs and found pin-hole contraction of one or both pupils, which persisted to within a few hours of death. He observed hundreds of sick cats, dogs, rabbits, etc., and none presented contracted pupils excepting those affected with rabies. H. K. Miller, of the N. Y. Canine Infirmary, agrees that this symptom is peculiar to rabies alone. Coakley therefore believes contracted pupils in a suspicious canine is a *pathognomonic sign of rabies.*

Reaction of the pupil. It is customary to state that the normal pupil reacts to light. By this is understood that a contraction of the sphincter iridis follows the impulse of light on the retina. This reaction has been fully discussed and explained in this section under *Physiology of the pupil.* But it is just as true and as scientific to state that the normal pupil reacts to *darkness,* for the dilator pupillæ is stimulated in darkness and the normal pupil expands to the limit in the absence of light. Dilatation of the pupil in darkness is brought about by inhibition of the pupillomotor afferent and efferent pathways causing relaxation of the sphincter, aided by stimulation of the dilator pupillæ fibers in the iris from impulse travelling along the course of the cervical sympathetic pathway. Just how this dilating impulse travels is not so well known but it is probable that the impression created by darkness on the retina is conveyed along an intracerebral chain of neurons to centers in the medulla and finally to the ciliospinal center in the cord, from which latter the sympathetic fibers have their origin. The various normal reactions of the pupil are explained elsewhere in this section (see *Direct, Indirect or consensual, Associate, Psychic and Sensory reaction*).

These reactions have been studied as regards their clinical significance so that any pupillary inequality, abnormal reaction, dilatation, contraction or rebounding, arouses in the mind of the physician the suspicion of either local or cerebro-spinal disease, and a valuable clue as to the patient's condition is at once afforded. In the case of poisons or unconscious states from any cause the condition and behavior of the pupils are the most valuable practical symptoms we have at our command in determining the true state of the patient.

Reactions after optic neurectomy. Schreiber (*Arch. of Ophthal.,* LXI, 3, p. 570) found after severing the optic nerves in rabbits, both as regards its orbital and intracranial position, that by squeezing its ears together at the roots the pupils contracted.

In these same rabbits the pupil would contract upon irritating the cornea or forcibly opening and closing the eyes. We must assign the reaction to some influence other than the effect of light, for blindness was total. No doubt the contraction was cortical through the pathway of the third nerve which was uninjured. Maximum dilatation of the pupils could be induced by slapping the rabbit's abdomen. This was doubtless due to stimulation of the sympathetic.

Red shine. Pupils that shine in the dark. Occasionally one of the laity will exclaim, "your pupil shines like fire." This phenomenon has been noted in the open air but more frequently in a room lighted artificially. It is the so-called "red reflex" which we see more brilliantly demonstrated with the ophthalmoscopic mirror and is but the reflected light from the choroidal circulation which enters the observer's eye. Our pupils ordinarily appear black because the only reflected rays that will elicit the red shine are those that pursue in their reflection from the bottom of the eye the same path which they took in entering. Our own eyes not being sources of illumination can not see the direct ray for that is sent back to the real source of illumination, be it a candle flame, arc light or what not. The pupil appears black for the reason that no rays are emitted from the bottom of the eye other than the direct rays just mentioned. When we peep through the hole in the ophthalmoscopic mirror we see these direct rays reflected back to the source of illumination and the pupil appears to "shine like fire." How then can we explain the occasional glint that we note in the pupil when we are not using this mirror or a similar device?

If a person is in a dark place, like a cellar, and you look in through the only window at his face you will see his pupils shine because the sky back of your head is the source of illumination and your own eyes "catch," as it were, the directly reflected light from his pupils which thus appear to shine.

Occasionally too, in a room lighted by artificial lights, while you are wearing your flat lenses the light is reflected into your companion's eye from the surface of your own spectacle lens and you again catch the directly reflected rays and his pupil shines. Indeed, Helmholz first took several pieces of flat window glass and reflected the light purposely in a patient's eye looking with his own eye through the clear glass to study this red shine. Seeing the red reflex he was led to suppose that by holding in front of the eye a convex lens of two inches focus he would be able to see the fundus. This he did and this was the first ophthalmoscope. But while the above may stand as being true as regards the human eye, we must concede that the argument will not stand in reference to animal's eyes which appear to shine regardless of the source of illumination. Indeed they seem to shine from power which is possessed within the eye of the animal itself. (See *Cat-like refulgence,* also *Albinism* in this section.)

The red shine in the eyes of ruminants and pachyderms is due to an anatomical structure in their retina of which the human possesses only a vestige (the elastic layer of Sattler) being the so-called *tapetum* or in the case of animals just mentioned, the *tapetum fibrosum,* in carnivora called the *tapetum cellulosum.* "The pigment of the retina being wanting over certain definite areas, light falls upon this opaque layer and is totally reflected at certain angles causing a lustrous iridescence that gives rise to the popular belief that the eyes of animals may shine in the dark.'' The iridescence is caused by slight irregularities of the reflecting surfaces being an interference phenomenon that is seen in mother-of-pearl. (Baker in Norris and Oliver's *System of Diseases of the Eye.*)

Reflex contraction, Studies in. Starke (*Nederland, Tydschr. voor Geneesk.*, 1909, Bd. II, No. 15) postulates the general law well known in neurology that ''the higher the nerve tract the greater is the energy released.'' He then calls attention to there being two fundamentally different systems acting upon the sphincter pupillæ: (1) the lower tract connected with the corpora quadrigemina, and (2) the higher with the pulvinar thalami optici. When the attention is associated with light stimulus both systems are energized and we have the strongest physiological contraction of the pupils. The reflexes from accommodation, convergence and light travel via quadrigeminal tract and everything that detracts the attention inhibits these reflexes and act to dilate the pupils.

Reflex pathways, Pupillary. According to C. Barck (*Ann. Ophthal.*, Jan., 1915, Vol. XXIV, No. 1, p. 39) we owe the exact knowledge of the pathway of the pupillary fibers to the researches and elaborate experiments of Bernheimer (1899). He proved that not only the visual but also the pupillary fibers undergo a semidecussation so that each eye sends pupillary fibers to both reflex centers. The course is as follows: They run in conjunction with the visual fibers into the lateral geniculate bodies. There they depart from the visual fibers, run along the inner border of the inferior corpus quadrigeminum where they form a compact stratum. This stratum runs in a curve convexly upward to the superior corpus quadrigeminum and enters its substance in the form of a fan. There, in the superior corpus quadrigeminum we have the reflex center.

Bernheimer was furthermore the first to prove anatomically the connection between this center and the nucleus of the third nerve. Out of the superior corpus quadrigeminum connecting fibers run around the lateral wall of the aqueduct of Sylvius to the nucleus of the motor oculi which is located just below the aqueduct. Bernheimer supposes that the nuclei of the third nerves are also united by communicating fibers. If this is true, there exists a two-fold possibility by which irritation of one eye can produce a pupillary reflex of the fellow eye. (See *Physiology of the pupil* in this section.)

Retinal circulation, influence on the pupil. Bach says changes in the retinal vessels, especially the arterial, with consecutive atrophy cause decrease in the pupillary light reflex. When the blood supply of the retina is cut off by the plugging of the central artery the light reflex disappears with the loss of sight. If one or more branches are affected light thrown on the affected area causes a poor reaction of the pupil. Hemorrhages in the macula act like central chorioretinitis, though two cases of fresh macular hemorrhage were noted where no change in size or reaction of pupil could be made out. (See *Embolism of the central artery* in this section.)

Retinitis pigmentosa. Bach states that in retinitis pigmentosa the light reaction is decreased, and more so when the light is thrown on the periphery than when it is thrown on the macula. The nature of the visual field in retinitis pigmentosa, together with the common symptom, night-blindness, explain the dilatation in dim light noted in these cases.

Retrobulbar optic neuritis. Bach states that in retrobulbar neuritis the pupil of the affected side is as a rule slightly larger. The direct reaction to light in the affected eye and the indirect reaction from the other eye is decreased. In one case an increase of light reaction preceded by three days an increase of visual acuity.

Tarle (*Klin. Mon. f. Aug.*, Vol. LIV, p. 412) reports twenty-nine cases of acute retrobulbar neuritis among whom he found eight presenting inequality of the pupils. Among these only four had one eye affected. (See *Multiple neuritis* in this section.)

Retroflexion of the iris, Complete. Hubbell, of Buffalo,(*Ophthal. Rec.*, Aug., 1901, p. 421) reported the case of a patient who had fallen from a wagon striking the left side of his head on the pavement causing hematoma of the eyelids, chemosis, hazy cornea, hyphemia, hypotonia, etc., but no laceration or abrasion of the conjunctiva or cornea. When the blood disappeared from the anterior chamber there was found no trace whatever of the iris, ciliary body or lens. The fundus was perfectly normal. The vision was 20/50 with a + 11.0D lens. Consultation with other ophthalmologists resulted in the belief that the lens had been absorbed and that the iris had been retroflected throughout its whole extent. (See *Pectinate ligament* in this section.)

Rib, Sympathetic paralysis from cervical. Mayou (*Ophthalmoscope*, June, 1916) reported two cases of paralysis of the sympathetic associated with cervical rib. The first was a girl of nine years who presented miosis and ptosis of the right eye with enophthalmos and diminished sweating on the right side. The second was a female of forty-six years presenting the same symptoms referable to the left eye. Cocain solution failed to dilate the pupil in this case. In each, the X-ray revealed the presence of a cervical rib on the affected side. (See *Brown-Sequard paralysis* in this section.)

Rigidity. By rigidity is understood loss of pupil reaction to the light but retained reaction to convergence and accommodation. The pupil may be rigid while dilated, rigid while contracted or, indeed, rigid while neither dilated nor contracted. The presence of a pupillary reflex center has been questioned because of the fact that in cases of rigidity the region described as being the location of the nucleus of reflex pupil contraction was found to be entirely normal (anterior colliculi of the corpora quadrigemina). Moreover, that the entire corpora quadrigemina have been found diseased and the patient *in vivo* presented intact pupils, and again in cases of ophthalmoplegia interna over many years duration that finally went to the post mortem table, it was found that the corpora quadrigemina and also the Edinger-Westphal nuclei were entirely normal. These observations and others of like nature have led Reichart to believe that independent rigidity of the pupil has no cerebral significance but that it is a sign of disease located in the spinal cord.

The experiments and observations of Wolff (*Archiv. f. Psychiatry,* Vol. XXXII, No. 1, p. 57) proves that the rigidity of the pupils is due to degeneration of the posterior columns in the upper cervical region.

Rigidity of the pupils has been definitely produced experimentally by bilateral division of the medulla oblongata at the spinal end of the fourth ventricle, and division of the medulla on the right side at this point has caused rigidity of the left pupil while the right pupil remained normal.

Exposing the medulla oblongata and without injuring it will diminish or even abolish pupil reaction for a short time, but if a cut be made in the middle of the fourth ventricle on each side in the *upper* part of the medulla this rigidity promptly disappears. This goes to show that there is a center at the spinal end of the fourth ventricle which acts as an inhibitory center for pupil reaction to light and from this we may argue that there are two reflex arcs for pupil reaction; one passing through the corpora quadrigemina and the other through the spinal end of the fourth ventricle close to the respiratory center. (Posey and Spiller, *The Eye and Nervous System,* p. 15.)

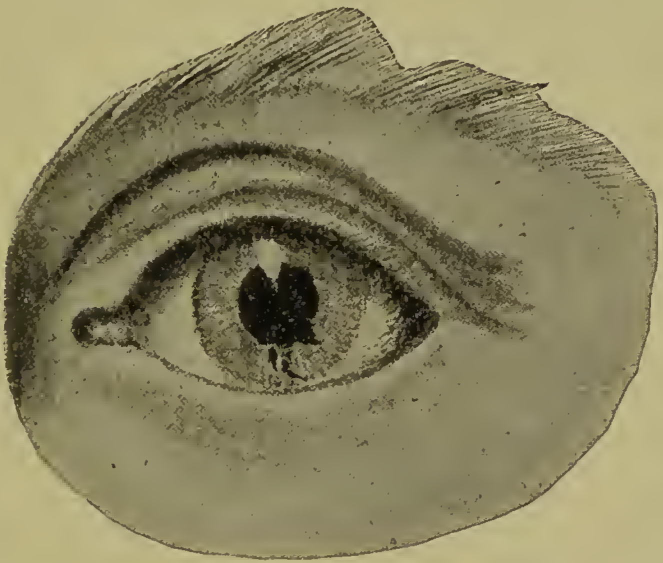
It is most likely therefore that in those cases of pupil rigidity in whom the corpora quadrigemina and adjacent nuclei were found normal the pathology involved the nuclei located in the spinal end of the fourth ventricle. (See *Pathology* in this section.)

Rupture of the iris, Indirect. Levinsohn (*Arch. of Ophth.*, Vol. XXXII, No. 2, p. 134) studied the effect of contusions on the eye in which the outer coat was not ruptured, but where there had been a blow on the ball which caused a momentary indentation. Ruptures of the iris were very common in this kind of injury, the most frequent being at the pupillary margin. The effect is dilatation of the pupil, and this dilatation is generally elliptical in form. It is not known whether these lacerations at the sphincter margin of the iris are due to the back-kick of the aqueous which lies behind the iris, or whether there is forcible dilatation of the pupil during contraction impulses causing rupture of the sphincter. In almost every case the pupil is seen to be dilated immediately after the injury, but in the course of time the dilatation is less pronounced. The anatomical arrangement of the fibers of the dilator pupillæ favors their defense when a blow is sustained on the eyeball, and the converse is true regarding the circular muscle, for the strain comes heavily on the latter. The effect of such a blow must also tend to paralyze the nerves supplying the iris. This is proven by the effect of mydriatics which in a non-injured eye causes the paralyzed pupil to dilate still further, but in an eye that has sustained a direct injury of the kind referred to, the pupil does not dilate in the same manner. It is not unusual to find the pupil dilated slightly after such an injury for the balance of the patient's life, but it reacts to the light in most cases. Moreover, the contour of the pupil is usually permanently deformed. A peculiar reaction to eserin has been observed, the drug causing the pupil to dilate still further, the explanation of this paradoxical action is that there was complete paralysis of the sphincter and hence eserin could not cause it to contract, but by stimulating the dilator fibers may cause the pupil to dilate.

Levinsohn finally concludes that in this class of injuries there is a marked paralysis of the sphincter and a less marked transitory paralysis of the dilator muscles of the iris; the latter recovering fully, the former partially in the course of time.

Sweet (*Ophthal. Rec.*, July, 1901) draws a distinction between mydriasis due to paralysis of the sphincter from peripheral stunning of the nerve fibers supplying the iris, and mydriasis due to rupture or laceration of the sphincter which breaks its continuity. Many cases of both kinds of mydriasis are reported. Sweet's case showing a gaping rupture or laceration of the sphincter is well illustrated in the accompanying illustration. The man, age 58, was struck obliquely across the orbit and mallar bone at an angle of 135 degrees by a falling bed post. The pupil measured 5 mm. in its shortest diameter and 7½ mm. in the angle of 135°. The lens was found dislocated in the floor of the vitreous chamber.

Salvarsan. Posey (*Trans. Wills Hosp. Ophth. Soc.,* Feb. 6, 1911) reported the case of a syphilitic whose pupils were occluded by dense synechiæ with partial iris bombè and plus tension. The vision was gradually reduced (fingers at three feet), antispecific treatment had been used without avail and no improvement occurred from local or constitutional treatment. The patient, a woman aged twenty-two, was then given salvarsan intravenously and after forty-eight hours great improvement set in. In four days the eyes were free from inflammation and the vision greatly improved.



Sweet's Rupture of the Iris at Pupillary Border.

deSchweinitz (*Trans. Phila. Col. of Phys., Ophth. Sec.,* Oct. 20, 1910) reported a case of gummatous iritis with pupil disturbance which was rapidly cured by the intravenous injection of salvarsan.

Loeb (*Ann. Ophth.,* July, 1914) noticed a violent recrudescence of inflammation of the iris following one injection of salvarsan in a positive case of syphilis in a young woman. There were about one dozen reddish elevations in a circular arrangement around the margin of the pupil which we are led to suppose were miliary gummata. The recovery promptly occurred after the administration of mercury and KI. The gummatous iritis occurred four months after the injection of salvarsan. The frequent occurrence of optic neuritis and consequent atrophy and blindness after the use of salvarsan in cases of syphilitic lesions of the iris has led to much caution in its employment for intraocular syphilis. (See *Arsenical neuritis* in this section.)

Sarcoma of the choroid, The appearance of the pupil in. It is not unusual for melanotic cancer of the choroid to grow forward, displace the root of the iris and cause flattened pupil on that side; with this soon occurs cataract and increased tension. Cases of sarcoma of the ciliary which have grown around the lens and presented in the pupil have been reported.

Scotoma. The pupils in large central scotoma are usually dilated. The patient soon acquires a confirmed eccentric fixation and the accommodation is not used. The pupils are dilated but react somewhat to the light.

Scotoma, Scintillating. Swift (*Jour. of Ophth. and Lary.*, May, 1916, Vol. X, No. 5, p. 137) states that he has noticed dilated pupils in this disease. He believes the dilatation is due to fear and that it is therefore psychic.

Seclusio-pupillæ. This is a term used to express complete adhesion between the pupillary margin and the lens, without organized lymph in the pupil space. It is to be taken as evidence of a recurrent plastic iritis.

Sclerosis, Posteriolateral. The pupils are usually normal in this disease. Weisenburg (Posey and Spiller, p. 502) found them equal in size and normal in reaction. But Gowers (*Disease of Nervous System*, Vol. I, p. 506) has observed rigidity of the pupils to light in three cases, and in one case there was loss of accommodation-reaction and retention of reaction to light. It is thought that when the pupils show abnormal behavior in this disease there is a syphilitic infection present.

See-saw pupils. Geronne (*Zeitschr. f. klin. Med.*, No. 50, p. 377) observed difference in the size of the pupils with prompt reaction in a patient with mitral stenosis and insufficiency. At one time the left pupil was the larger; at another time the right pupil was the larger. This change was frequently observed, and at other times the pupils would be of the same size. He ascribes the phenomenon to the influence of the abnormal heart on the cardiac branches of the sympathetic nerves. (See *Cardiopathies*, also *Springende* and *Changing pupils* in this section.)

Sensory reflex, Reaction of the pupil to psychical and sensory stimuli. Heubner (*Arch. f. Phsych.*, XLI, p. 1016) found that nearly every profound psychical process was accompanied by dilatation of the pupil. The pupils will also dilate when painful pressure is made on organically diseased parts but this latter reaction does not take place in psychogenetic pain. This test may therefore be employed to establish a definite diagnosis between organic and psychogenetic pain. The pupils in tabes do not dilate when the neck is pinched or on painful pressure on an inflamed part. This is not to be wondered at, for the sympathetic pupillary fibers are paralyzed in tabetics. (See *Trigeminus-facial pupillary reflex.*)

Senility. D. W. Greene (*Ophthalmology,* Jan., 1908) reported on his findings as regards many conditions of the eyes of 500 retired soldiers past 60 years of age, inmates of the National Military Home at Dayton, Ohio, and he also noticed the following as regards their pupils: The inter-pupillary distance measured 62 mm. The average size of the pupil was 3.3 mm. The dilatability of the pupil with one per cent. solution of homatropin was exactly twice the normal size, e. g., if the pupil measured 3.5 mm. before dilatation it would measure 7 mm. after, etc., but if the individual was over 70 years of age the pupil would not dilate to quite double the normal size, e. g., a 3 mm. pupil would dilate to 5 mm. in diameter. This was not always the case. Greene noted a close and constant relationship between the diameter of the cornea, the size of the pupil and the dilatability of the pupil with the mydriatic drug. No case of glaucoma developed from the use of the mydriatic in these 500 men all past sixty years of age.

Skiakineskopy through the pupil. Holth (*Norsk. Mag. f. laevidensk.,* 1904, p. 1072) reports a new discovery which enables the patient to determine his own refraction. It consists in observing the behavior of the shadow in one's own eye when an object narrower than the pupil is moved back and forth directly in front of the eye while fixing the gaze on a luminous point. Myopes see the shadow moving with, hypermetropes against, the movement. Emmetropes see no shadow. Astigmatism can be accurately diagnosed and the axis determined. Slight degrees of ametropia can be detected and accurately estimated so that the test is both rapid and delicate.

Skiascopy. In the so-called "shadow test" we observe by means of a reflecting mirror the behavior of the red reflex as seen in the pupil when studied at the distance of one meter or beyond, during a series of to-and-fro movements of the light reflected in various directions across the pupil. The play of light and shadow in the pupil during this test reveals the refractive state of the eye to a trained observer. This is a most valuable test as it is entirely objective and affords at once a great guide in the determination of the refraction as a diagnostic measure, but unfortunately it is not to be relied upon to the exclusion of other tests. (See *Pupil stop* in this section.)

Sleep. Max Knies explains the ptosis and contracted pupils found in normal sleep by assuming that there is suspension or paralysis of action of the cervical sympathetic supplying the levator palpebræ and dilator pupillæ muscles. The withdrawal of consciousness in slumber puts at rest all psychic or cortical impulses to the sympathetic nervous system, and the pupils contract because the impulses which cause them to dilate are in abeyance. If the eyelids are closed while the subject is awake the pupils do not contract, on the contrary they dilate. Closing the eyes does not suspend cerebral actively and the influences of the cortex through the sympathetic is active.

Spastic mydriasis. Spastic mydriasis is that condition in which the pupil is dilated but reacts to light and convergençe; it is met with where there is stimulation of the cervical sympathetic from any cause, central, intermediate or terminal, also in rare intracerebral tumors which do not directly involve the pupillary centers by pressure but inhibit these centers through interference with the communicating fibers to and from the cortex. Spastic mydriasis also exists in acute mania through cortical influence, occasionally premonitory locomotor ataxia, and sometimes after epileptic seizures.

Bumke (*Centralbl. f. Neur. u. Psych.*, Oct., 1903, p. 41) observed spastic mydriasis in fifteen cases of catalepsy, also in subjects presenting marked anemia and imbecility. Spastic mydriasis may exhibit from spinal cord irritations as from intestinal worms, acute intestinal indigestion in children from gorging and also from teething. (See *Dilatation, abnormal,* in this section.)

Sphenoidal disease. Posey (*Trans. Wills Hosp. Ophth. Soc.*, Feb. 6, 1916) presented a case of double papilledema from sphenoidal disease in which the right eye was blind and the left had 20/50 vision. In this case the right pupil was 5 mm. and did not react to light, while the left was 4 mm. and sluggish in reaction. Unfortunately the pupils do not present pathognomonic localizing evidence of disease in the sphenoid.

In Posey's case the pupils behaved like we would expect them to in blindness of one eye and half-blindness of the other from any cause.

Wallis and Wood (*Lancet,* 1910, Vol. II, p. 937) observed optic neuritis and blindness from empyema of the sphenoidal sinus although there was a retained patch of sight in the temple field of vision. When this part of the field was illuminated the pupil responded slightly. This case again demonstrates that the response of the pupil bears a close relationship with retained sensibility of the retina and that when the retina is dead the pupil no longer responds excepting in the unusual cases referred to. (See *Pupillomotor fibers retained action in blindness,* also *Nasal disease* in this section.)

Sphincter, Location of the center for the. Bernheimer (Graefe's *Archiv.,* III, p. 382) experimenting on monkeys in order to locate the nuclear center of the sphincter pupillæ, destroyed the right, small-celled, median nucleus and as a consequence obtained permanent reflex iridoplegia. He therefore believes this without doubt to be the location of the sphincter-center. The third nerve and the optic nerve were unaffected in this experiment. (See *Physiology of the pupil.*)

Sponge-iritis, The pupil in. In this disease there is a plastic exudate which fills the anterior chamber, making a complete cast. The pupil is consequently rendered very dull and difficult to see. It is usually contracted and the patient becomes quite blind. In a few days the plastic exudate begins to contract and exposes a clear zone, especially around the upper edge. In ten days or two weeks the fibrinous exudate entirely disappears leaving the pupil clean, black and perfectly normal. The condition is therefore alarming but the prognosis is good. H. Knapp observed this phenomenon in a few cases after cataract operation. Exudations occur in the pupil also, as the result of traumatism of a perforating or non-perforating character but these are more slowly resorbed and often result in permanent damage in the shape, size and function of the pupil.

"Springende" mydriasis. Gessner (*Muench. Med. Wochenschr.,* March, 1901) states that we are to understand by this phenomenon, a dilatation of the pupil which affects alternately one eye and then the other and that, too, by uniform light conditions. He reports a case which ran as follows:

Nov. 10, right pupil larger than left; Nov. 11, left pupil larger than right; Nov. 12, right pupil larger than left; Nov. 15, in the morning right pupil larger than left, in the afternoon left pupil larger than right; Nov. 18, right pupil larger than left; Nov. 19, pupils equal; Nov. 24, right pupil larger than left, and so on.

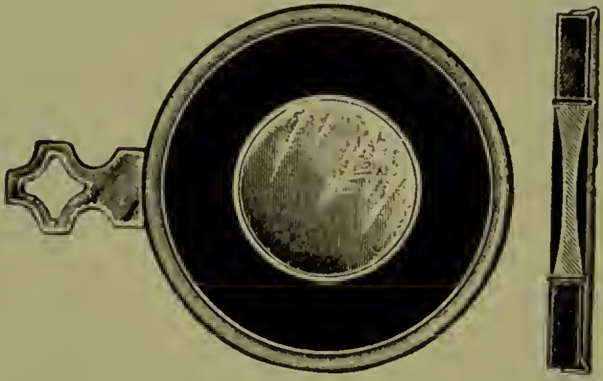
This rare variety of mydriasis, according to some observers, is seen in those who have some organic lesion of the nervous system (paralysis, tabes, etc.), and also neurasthenia. (See *See-saw pupils, Changing pupils* and *Pathology of the pupil.*)

Stereoscopic trick. Elmer (*Col. Phys. Phila., Trans. Ophthal. Sec.,* Oct. 20, 1910) demonstrated that the pupil will contract when looking at the photograph of an object in the foreground, and dilate when looking at one in the background, in a stereoscopic picture taken with a single camera where two impressions are taken on the same plate the one focused for near objects the other for distant objects.

Holloway who investigated the phenomenon and regarded it originally with Elmer thought it was a psychic influence rather than accommodation. He tried to prove the test on three persons and found that in two no such change could be noted; in one, however, there was a slight reaction of the pupil which was better expressed as a hippus or possibly an adaptation of the pupil. Further testing is needed to prove this interesting pupillary phenomenon.

Strabismus concomitans. Bach states that in strabismus concomitans the pupils are equal and the reaction is normal on both sides, even when acuity of vision of one eye is greatly reduced.

Subjective examination of the pupillary reflexes. Gradle (*Arch. of Ophth.*, Vol. XLIII, No. 4) describes a subjective method of examination of the pupils suggested to him by Kraupa of Elschnig's clinic. The patient must be fairly intelligent. "One eye is closed and immediately before the other is held a bi-concave lens of either 30 or 40 D. strength, when a light of not more than eight candle-power held ten to fifteen feet in front of the patient is then switched on. Through the lens the patient sees a circular disk of light which immediately contracts. This disk is merely the image of the divergent rays passing through the lens and bounded by the pupillary edge of the iris. The greater the contraction of the pupil, the smaller becomes the disk."



Pupillary Reflex Lens. Gradle.

He is also able to test the consensual pupillary reaction by placing a ground glass blank before the other eye. The eye under the blank is covered with the hand and the light is turned on as in the direct test. As soon as the pupillary contraction has taken place, the hand is removed from the eye and the patient sees the disk of light contracting still further. The kind of lens Gradle recommends is shown in the illustration. (See *Haab's reflex,* also *Pupil, Measurement, and exact size of.*)

Sympathectomy, The influence of on the pupil. The superior and middle cervical ganglia have been removed for the relief of glaucoma. At one time it was thought this treatment was the happy solution of the glaucoma problem and many such operations were performed.

Among others, Black (*Ophth. Record,* Vol. X, No. 10) reports on the pupil phenomena that follow this operation. While the patient was still on the table after the ganglia were extirpated and the wound was being dressed the pupil became contracted. Before the operation the pupil was dilated and fixed. Six hours later the pupil measured 1.5 mm. and the tension of the eye was normal. Ten days later the pupil was 2 mm. in a well lighted room and dilated slightly in a darkened room. There was distinct response of the pupil to the act of accommodation. Cocain did not dilate the pupil. As time passed the pupil gradually became a little larger so that nine months later it was 4 mm. (See *Glaucoma simplex,* also *Ganglionectomy* in this section.)

Sympathetic nerve, End-organs of the, in the iris. Shock (*Arch. f. vergl., Ophthalm.,* I, 3, p. 293) has found by microscopic examination of the iris of various mammals that there are unipolar, bipolar and multipolar ganglion-cells present in this membrane which represent the terminal filaments of the sympathetic nerve. The processes from these ganglion-cells form a net-work which is in intimate connection with the stroma cells of the iris. Some of them enter the bodies of the stroma cells, others lie in such close contact that the nature of their attachment cannot be determined.

Sympathetic miosis and ptosis. The cervical sympathetic nerves aside from supplying the radiating muscular fibers of the iris also supply *Muellers' muscle* which assists the levator palpebra superioris. Hence it is that miosis due to degeneration or lesion of the ciliospinal center is frequently associated with partial ptosis, and hence also is explained the slight dilatation of the pupil noted in Basedow's disease which is associated with retracted lids due to spinal irritation. The sympathetic nerve coming from the spinal cord has an anastomosis with the third nerve and also the first division of the fifth nerve in the cavernous sinus. This anatomical fact may account in part for the occasional coincidence of ptosis and miosis. One would naturally think that since in ptosis there is a restricted admission of light within the eye the pupil in these cases would always be dilated. The ptosis associated with ophthalmoplegia externa is usually accompanied by contracted pupils.

Sympathetic nerve and ciliary ganglion. Max Knies (see his text-book) states the motor sympathetic fibers of the eye are derived from the superior cervical sympathetic ganglion and pass through the carotid plexus. Centrally they are governed by the lowermost part of the cervical and first dorsal part of the spinal cord. Irritation of this part of the cord causes spasm of the dilator pupillæ (mydriasis) and paralysis causes loss of function of the dilator pupillæ (miosis).

The motor, sensory and sympathetic nerve fibers for the interior of the eye and the cornea pass through the ciliary ganglion. This ganglion receives three roots and gives off the ciliary nerves to the interior of the eye. These three roots are: (1) The motor root which is a branch of the third nerve furnished from a strand of this nerve which supplies the inferior oblique muscle.

(2) The sensory root is a branch of the fifth nerve given off from the naso-ciliary nerve.

(3) The sympathetic root is derived from the carotid plexus in the cavernous sinus and passes through the sphenoidal fissure.

Any one of these roots may be paralyzed, producing in the first case paralysis of the sphincter pupillæ (mydriasis), in the second, loss of sensation and in the third, paralysis of the dilator pupillæ (miosis). (See *Ciliary ganglion* in this section.)

Sympathetic, Paralysis of the cervical. Schur (*Zeitschrift. f. Augenheilk.*, XXVI, No. 4, p. 335) has studied 34 cases of paralysis of the cervical sympathetic. In all cases sensory and psychic stimuli caused a dilatation of the pupil on the paralyzed side. This supports the view of Brauenstein that the impulse to dilatation from these stimuli is conducted along the oculo-motor tract to the iris, causing relaxation of the tonicity of the sphincter thus assisting the action of the dilator on the sound side. Slight dilatation of the pupil was produced with cocain. This is interesting as going to prove that cocain does not stimulate the terminal filaments of the dilator nerves for they are paralyzed and not subject to stimulation and so the slight dilatation noted must rather be ascribed to relaxation of the tonicity of the sphincter by the drug, aided also by contraction of the blood vessels of the iris.

The withdrawal of the nervous impulse along the sympathetic to the dilator pupillæ from paralysis permits the contraction of the sphincter and causes miosis. Schur found in his 34 cases that the pupil will dilate slightly on the paralyzed side but not so much as on the healthy side, and as above stated he ascribes this to withdrawal of contraction impulse to the sphincter iris along the motor-oculi tract.

Rosenfeld (*Münch. med. Wochen.*, 1904, No. 45, p. 2001) reports a case of carcinoma of the esophagus which included the right cervical sympathetic in the neighborhood of its lowest ganglion. Besides the classical symptoms of paralysis of the sympathetic (miosis, ptosis, etc.), it was noted that the pupil dilated markedly when painful pressure was made on the affected area.

Sectional dilatation of the pupil. Braunstein (*Ein. Beitrage z. Kent. d. Innervat. d. Iris be weg.*, 1893) proved by experiment that stimulation of the temporal of the two long ciliary nerves causes a dilatation of the outer half of the pupil, while stimulation of the trunk of the cervical sympathetic after division of the temporal of the two long ciliary nerves caused dilatation of the inner lower half of the pupil.

The converse of this would be contraction of the pupil and corectopia inwards due to paralysis of the external of the long ciliary nerves from deep burn or perforating wounds which divided its trunk, etc., in which case the inward half of the pupil would react in making the direct pupillary reaction test. (See *Deformed pupil* in this section.)

Sympathetic reflex, Diagnostic value of. Hirschl (*Wien. Klin. Wochen.*, 1899, No. 22) explains the normal sympathetic reflex action of the pupil to be a marked dilatation from pricking or pinching the cheek or applying a moderately strong faradic current of electricity to any part of the body. This reaction is wanting in progressive paralysis even when the light reflex is preserved. In all mental disorders (apart from progressive paralysis) the reaction was almost always present, the exception being in the case of chronic alcoholism where it is absent.

Sympathetic tract, Cervical, supplying the dilator pupillæ. The nucleus of origin of the dilator pupillæ is hypothetically located in the medulla. The neurons pass down the lateral columns of the spinal cord as far as the third dorsal nerve to a certain location in the cord known as the ciliospinal center. Other neurons beginning at this center emerge in the first, second and third dorsal roots and pass on to the inferior cervical ganglion, passing en route through the stellate ganglion and annulus of Vieussens; from the inferior cervical ganglion they pass on to reach the superior cervical ganglion near the angle of the lower jaw. This ganglion acts as a relay station similar to the ciliospinal center where other neurons take the impulse and carry it forward to receive branching neurons from the Gasserian ganglion and plexus around the internal carotid; thus reinforced, as it were, they travel on to join the nasal branch of the first division of the fifth nerve to form the long ciliary nerves to finally reach the ciliary muscle and iris. (See J. Herbert Parsons' diagram at the beginning of this monograph.)

Sympathetic, Miosis in gunshot-wound of cervical. Harlan (*Ann. Ophthal.,* April, 1901) states that though many cases of paralysis of the cervical sympathetic from pressure of morbid growths are on record, particularly from enlargement of the thyroid and lymphatic glands, the reports of cases of paralysis of this nerve from direct traumatism have been extremely few. This is explained by the fact that "the anatomical situation of the sympathetic is such that it is almost impossible to injure it with a missile without at the same time disturbing other structures which result fatally." (Mitchell, Morehouse and Keen in *Gunshot Injuries of the Nerves.*)

Harlan reports the case of S. R., age twenty-two, who had been shot in the neck by a rifle ball five years before and who presented the classical signs of paralysis of the cervical sympathetic, the sympathetic ptosis of Swansy, the distinct miosis, the enophthalmos, etc. The scar in the neck was located on the anterior margin of the right sterno-cleido-mastoid muscle at a level with the cricoid cartilage. The right pupil measured two and half mm. while that of the left measured four and a half mm. (See *Argyll-Robertson monocular* in this section.)

Sympathetic ophthalmia. The pupil in sympathetic ophthalmia becomes blocked with organized lymph in which are found wandering pigment cells from the iris. There may be seclusio-pupillæ in mild cases or occlusio-pupillæ in severe cases. The tension of the eye may become raised. This secondary glaucoma arouses the temptation to perform an iridectomy. If iridectomy is attempted in this state of affairs the eye becomes very bad. The coloboma produced by the iridectomy is quickly filled with plastic exudate and there is a vicious reaction with subsequent phthisis bulbi.

Syncope. In a fainting spell the pupils are always dilated and do not react to the light. Contraction gradually returns with returning consciousness.

Syphilis, Acquired, Early pupillary symptoms of. Sulzer (*Ann. Dermatol. et. Syph.,* March, 1901) calls attention to the frequency of anomalies of pupillary reaction in the early stage of acquired syphilis. Among fifty-three cases examined by him there were contracted, fixed pupils in eleven. These disturbances appeared within three months after the primary affection and in general they were transitory. (See *Argyll-Robertson pupils* in this section.)

Ayer (Knapp's *Archives,* XLV, No. 1, p. 16) finds that testing the spinal fluid for evidence of syphilis has yielded much valuable information among one hundred and sixty eye cases presenting signs of disease of the cerebrospinal system. He has found it exceptional to encounter a case of advanced syphilis of the nervous system with normal pupils. The Argyll-Robertson pupil is the rule, but there are many cases presenting this type of pupil which show no other signs of syphilis. He encountered thirteen such cases and among them nine were proven by the spinal fluid tests to have syphilis. The pupils are no indication that the disease will progress for many such cases have inactive or quiescent syphilis. The same general observations were made in reference to irregular pupils with the exception that among thirteen such cases the spinal fluid tests failed to reveal syphilis although seven of them gave a positive history. Such cases, while undoubtedly of syphilitic origin, should be regarded clinically negative, or at least as having quiescent syphilis. Among twelve cases presenting normal pupils Ayer found positive syphilis present as demonstrated by spinal fluid testing. Moreover, they presented other signs of active syphilis.

He states therefore that we may regard contracted irregular and unequal pupils as placing the patient under the suspicion of syphilitic infection, but we cannot declare from this symptom alone that the infection is active, and conversely, normal pupils do not preclude the existence of active and severe syphilitic processes.

Syphilis, Diagnosis in. The presence of typical Argyll-Robertson pupils declares for syphilis in nearly all, if not all, cases. And yet it is conceivable that a person who possesses symmetrical non-syphilitic lesions which disorganize the ciliospinal centers, or non-syphilitic symmetrical lesions of the pupil-dilatating centers in the medulla near the floor of the fourth ventricle, could present typical Argyll-Robertson pupils.

Syringomyelia. The pupils are usually not affected in syringomyelia. Among two hundred cases studied by Schleisinger pupillary disturbances occurred in only twenty-four. In a few cases the pupils were unequally dilated and when this was found it was thought to be due to some concomitant disease such as paresis or tabes.

There may be a cavitation in the region of the ciliospinal center in the cord, or above this area affecting the tract of the pupil dilating fibers. In such case miosis and other symptoms of paralysis of the cervical sympathetic are found. The symptoms may be more pronounced on or limited to one side.

Subconscious states, Mesmerism, Hypnotism, Somnambulism, etc. During the cataleptic or hypnotic state the pupils are dilated and fixed but if the subject be made to look at an object near at hand the pupils will contract. The pupillary reflex action to light stimulus if present at all is somewhat sluggish. In the state of complete fascination, profound abstraction, deep subjective mental states, somnambulism and the like, the pupils are found to be dilated.

The behavior of the pupils in these cases of unconscious orientation is in striking contrast with what is noticed in that other state of normal unconsciousness—sleep, in which we find the pupils contracted. (See *Psychic states*, in this section.)

Tabes. Collins, of N. Y. (*Med. News*, March 14, 1903) published the ocular data noted in his series of one hundred and forty cases of tabes dorsalis. He found loss of light reflex in 80 per cent. but the pupils responded to convergence and accommodation in 94 per cent. In 6 per cent. there was loss of contraction to accommodation and convergence proving that it is very uncommon for the pupils to lose their response to this effort. Miosis was very marked in 35 per cent and 26 per cent. more presented contracted pupils, 24 per cent. had medium-sized pupils and 6 per cent. had dilated pupils. The pupils were of unequal size in 25 per cent. of his cases. From this report we find corroboration of the common knowledge that in locomotor ataxia the pupils usually, though not invariably, present symptoms which are fairly constant and of distinct diagnostic value.

While approximately 80 per cent. of cases of tabes will present contracted pupils there remain in tabes other variations which should be known. The pupils may be normal or even dilated. The Argyll-Robertson phenomena, viz., loss of direct reaction and retained associate reaction, may be present in the latter of these. In cases of normal sized and dilated pupils optic nerve atrophy is often observed. When atrophy of the optic nerves is total the pupils may become dilated and rigid. The presence of unequally contracted pupils is a very common observance in tabes, the statistics of many observers on this point agree that anisocoria was present in from 27 per cent. (Berger) to 60 per cent. of cases (Vaughn). Unequal pupils *per se* are of no pathological significance for they are often noted in perfectly normal individuals, but taken in connection with other frank symptoms of disease the symptom becomes of much diagnostic value.

The loss of light reflex on the pupil in incipient tabes makes itself manifested gradually, hence it is that in what may be called the pretabetic cases the pupil response to light is present though somewhat sluggish. This should be observed and if in the same case there is prompt and well-marked reaction to convergence and accommodation incipient tabes may be suspected. In very many cases of incipient tabes there are well-established Argyll-Robertson pupillary phenomena long before other symptoms are noticed. (See *Argyll-Robertson pupil* in this section.)

Tension, Influence on ocular. Grönholm (Knapp's *Archives of Ophthal.,* Vol. XL, No. 6, p. 617-642) after extended experiment and observation concludes that the tension rises during mydriasis and decreases during miosis in glaucomatous eyes, and also appreciably in normal eyes. Mydriasis reduces the tendency to decreased tension during convergence.

The changes in tension during the activity of the iris are probably due to the opening of the filtration channels during contraction and the narrowing of these channels during dilatation, aided somewhat by the increased volume of secretion and circulation during activity and diminished circulation in the eye during the period of rest. The physiologic action of the sphincter provides increased blood supply and increased secretion of aqueous and at the same time provides for increased outflow by opening the filtration angle during contraction of the pupil.

Glaucomatous eyes should not be kept in darkness, on the contrary should seek the light and be used in reading much of the time to keep the pupils contracted as long as they react well. Miotics should always be instilled in the non-operated eye and this eye must not be bandaged with the operated one. In suspicious eyes by placing the patient in darkness the tension will rise as a consequence of dilatation of the pupils if glaucoma is incipient. (See *Anatomy of atropinized eyes* in this section.)

Tension, The influence of intra-ocular, on the size of the pupil. Taking then, as a standard, the size of the pupil when the intraocular tension is normal (25 mg. mercury), we may formulate the rule that raised tension is associated with dilated pupil and that lessened tension is associated with contracted pupil. The reason for this may be argued, if not proven, by the following points:

(1) Paralysis of both dilator and contractor pupillæ through prolonged hypertony will result in dilated pupil. When both are paralyzed the pupil is dilated as in death.

(2) Raised tension obtunds the sensibility of the retina hence the impulse to contraction of the pupil is inhibited through the association between the retina and the pupillary light reflex arc. From this we may argue conversely that contracted pupil would be the state in lowered intraocular tension because: (1) The lowered tension allows the lens to recede, thus withdrawing the support to

the iris wholly or in part, and the sphincter being unopposed mechanically by the lens contracts somewhat. (This is not true in detachment of the retina.) (2) The withdrawal of normal pressure permits hyperemia of the iris, which causes the pupil to contract because the pupil space is the only available area in the plane of the iris which will permit encroachment from swelling of the iris. (3) The inhibitory influence of the normal tension on the iris musculature being withdrawn in hypotony the overpowering sphincter muscle will assert its strength, hence the contraction of the pupil.

Therapeutical value of alternate contraction and expansion of the pupil. Wandless (Knapp's *Archiv. of Ophthal.*, May, 1910, Vol. XXXIX, No. 3, p. 247) discovered that the alternate use of mydriatics and myotics exerted a decided effect on clearing the pupil-space of cataract débris. In traumatic cataract he secured 20/20 vision (with correcting lens) without operation by employing these remedies. He concludes that the ultimate resorption of lens substance is brought about by the mechanical shifting and slow agitation of the absorbable material by the action of the iris, aided by that of the ciliary, when under the influence of these drugs by affording opportunity to the aqueous to permeate the lens mass. The alternate use of mydriatics and myotics is of especial value in clearing up after-cataracts not due to inflammatory exudate. It is common practice to use atropin drops in all cases of traumatic cataract. The action of the drug tends to block the drainage channel as is well known. Thus the most sought desideratum, absorption of the swollen lens fibers, is inhibited. Eserin in solution contracts the pupil and opens the drainage channels. The alternate use of these drugs in solutions creates the best effect.

Since atropin dilatation of the pupil is difficult to overcome Wandless recommends homatropin drops instead, and in some cases he prefers 1 per cent. solution of pilocarpin to eserin on account of its lesser irritating effect.

The writer saw Prof. Deutschmann, of Hamburg, use atropin and eserin drops alternately in the treatment of acute plastic iritis with synechia, on the grounds that the mydriatic effect of the one and the miotic effect of the other severed the adhesions in many cases where mydriatics alone would have failed.

Threshold pupillary reaction and the extent of the pupillomotor area of the retina. For testing the threshold pupillary reaction Schlesinger, Erich and Berlin (*Deut. Med. Woch.*, Jan. 23, 1913, No. 4, p. 163) use a constant source of light such as acetylene. They noted the influence on the pupil of light passing through the sclera and also that of reflected light from the blind spot within the globe. They found that the size of the image of a luminous spot on the retina varies with the anomalies of refraction. Therefore they maintain that the same intensity of light has different pupillomotor values. To estimate this properly it is necessary to use an apparatus which will give the same luminous image on the retina in all cases, at the same time the influence of accommodation must be excluded. In order to meet these requirements Zeiss, of Jena, has constructed a "peri-pupillometer." The following is claimed: 1. In normal persons of the same age the threshold value is almost constant. 2. The pupillary reflex shows symptoms of exhaustion after repeated exposures to the light. 3. The pupil response becomes decreased after repeated illuminations with the same intensity.

It is a fundamental principle that any examination of the pupillary reflex area of the fundus must start with the determination of the threshold value of pupillary reaction. It was determined from observation that a weak light of the size of 1/50 of the optic disk directed upon the blind spot produces a pupillary reaction and with the perception of a halo but not if the intensity fell below from 0.3 to 0.4 candle power. Therefore only intensities of light should be used which permit light dispersion below the threshold value. They found that the radius of the pupillary reflex area of the retina equals at least 5 mm. in healthy persons of middle age. Hess found 3 mm. Schlesinger succeeded with his apparatus in ascertaining hemiopic pupillary reaction in two cases. (See *Adaptation of pupil reflex,* also *Pupillomotor area* in this section.)

Tic of the intrinsic muscles. Meige (*Ann. d'ocul.,* Vol. CXXIX, p. 167) states that there is in some cases a hippus-like tic of the pupils. This he regards to be invariably due to cortical influence and mentions its occurrence in stuttering patients.

Tobacco amblyopia, The sensory pupil reflex in. Dorrell (*Ophth. Record,* June, 1913, Vol. XX, No. 36) stated that the dilatation of the pupil which occurs when the skin of any part of the body is stimulated was, in tobacco amblyopia, either in abeyance or obtained only by increased stimulus. One hundred cases were examined by him. He found that the lowest stimulus which gives dilatation of the pupil in the normal eye is obtained from five to seven cells of the constant current battery, or approximately 3.5 milliamperes, the negative pole being applied to side of the neck. He used this method to determine tobacco poisoning in cases where there were no signs of nervous disease and found that in 121 such eyes the response to 3.5 milliamperes was present in only 20 per cent. Moreover, that in 50 per cent. no dilatation whatever could be produced even when the current was turned to the strength of the patient's tolerance. This test is useful in determining whether a patient is being harmed by the use of tobacco. In the class of cases showing frank nervous disease from tobacco he was able to obtain the pupil reflex in only 22 per cent. He mentioned that this behavior of the pupil might in some cases be blamed to the presence of locomotor ataxia and affections of the cord in tobacco users. Nevertheless, Dorrell's test becomes valuable because it is well known that in tobacco amblyopia the pupil usually responds to the light by the ordinary tests quite normally.

Tonsils, The pupils in systemic infection from the. Veasey (*Ophth. Record,* Vol. XXV, No. 8) found the pupils dilated in a case of chronic septicemia from degenerated and diseased tonsils.

Blum in the same journal reports iritis and contracted pupil from septic resorption from a carious tooth. (See *Dental.*)

Toxic amaurosis. Hopes had a case of antipyrin blindness in which the pupils were dilated and would not react to light or convergence. After pilocarpin sweats the pupils became contracted and active. In total blindness from quinin the pupils are dilated and fixed but in tobacco blindness in which there is always a peripheral field of vision the pupils are only slightly dilated and respond to the light. (See *Tobacco amblyopia* in this section.)

Toxic paralysis of accommodation with pupil symptoms. Hansell (*Ophth. Record,* March, 1916, Vol. XX, No. 3) remarks that the iris and ciliary body are usually associated in physiologic and pathologic action. That paralysis of one and not the other is usually due to nuclear or fascicular lesions. He notes that determination of the size and reaction of the pupil cannot be precise according to our present methods. Also that when the ordinary pupillometer (a round card containing perforations of graduated sizes) is held against the temple and comparison made with the size of the pupil the estimate is only approximately correct. He states that the dilatation of the pupil which is so often conjoined with amblyopia from toxemia cannot be classified as toxic paralysis of the pupil. That it is not dependent upon an affection of the nerves of the iris, but is dependent on the degree of amblyopia reaching its maximum when all perception is lost.

The morbid change in the optic nerves and retina due to toxemia interrupts the circle of reflex pupillary reaction and no stimulus to the pupil-acting center in the brain or cord can be carried by an optic nerve that is deficient in function. His contention therefore is that there is no toxic paralysis of the pupil *per se.*

Uthoff states that paralysis of the iris never occurs from toxemia, Hansell had a case, however, of excessive chronic alcoholism in which the pupils were dilated. The patient was an epileptic and it may be that dilatation was due in some way to the epileptic habit. The pupil in alcoholism is usually contracted, as is well known.

Hansell reported another case of dilated pupils in a man who had no known poison in his blood excepting that from a chronic specific urethritis. The pupils were widely dilated and only slightly responsive to light.

The effect of diphtheria poison in the blood is referred to as being a cause for paralysis of the pupil and was not infrequently met with in the days before antitoxin.

Hansell states, "The combined paresis of accommodation and of the sphincter pupillæ suggests a nuclear affection, possibly a hemorrhage, as both nuclei are close together and are supplied by the same nutrient blood vessels."

Ziegler, in discussing Hansell's paper, said he had seen a case of acute poisoning in a two-year-old child which produced marked miosis along with symptoms of prostration. He had to differentiate between opium, nicotin and muscarin. He was able to rule out opium but stated the child could have easily eaten a cigarette stump or a poisonous toad-stool found in the yard. He referred to Knies' assertion that muscarin in toad-stool and fish may cause miosis while tyrotoxin will cause mydriasis. (See *Quinine, Poisons* and *Pathology* in this section.)

Transillumination of the eyeball, The appearance of the pupil in. Friedenberg (*Trans. A. M. A., Ophthal. Sec.,* 1910) describes the appearance of the pupil by diaphanoscopy noted in various diseases of the eye. Corneal opacities were not demonstrable. Dense pannus cast only a slight shadow. Pigment deposits in the cornea produce absolute darkness. Cataract does not obscure the transillumination of the pupil. Membranous cataract only demonstrates where blood or pigment is present. Detached retina absolutely transparent. Melanosarcoma casts a deep shadow but non-pigmented sarcoma does not cast much of a shadow. Glioma of the retina is always transparent. He states, "Transillumination gives important information in many cases in which ophthalmoscopy is impossible and where oblique illumination alone teaches little."

Würdemann (*Ophth. Record,* Vol. XVII, No. 4) mentions the value of his transilluminator in studying the pupil, noting the condition of the abnormal lens and other intraocular affections as seen through the pupil. (See *Diaphanoscopy* and Würdemann's colored illustrations.)

Traumatic reflex immobility of the pupil. Axenfeld (*Deut. Med. Wochens.,* 1906, No. 35, p. 663) believes that in the cases of concussio oculi where the pupil does not respond to light, but does react to convergence, there is a paralysis of the pupillomotor fibers in the retina.

Traumatic neurosis and medico-legal cases. In true traumatic neurosis the pupils are rarely found to be affected. Inequality in size has been noted but normal eyes will present the same condition in about an equal proportion of cases. In hysteria or malingering cases claiming damages for alleged injury when one or both pupils are dilated, the use of eserin drops will often assist in establishing that fraud is being practiced, for in true paralysis the pupils will readily contract with their use. In case a mydriatic drug is being used no such ready contraction will occur. Hippus, if present in a case of traumatic neurosis, would assist in establishing the patient's claim for damages, for hippus is to be regarded as being due to an unstable nervous system or prolonged shock. However, we must not confuse the spurious cases where psychic influences and self-suggestion are taught to establish a pseudo-unstable state of the nerves, with the genuine cases where prolonged shock is truly present. In each of these hippus may be exhibited as a symptom.

Trigeminus reflex, Contraction in fifth nerve irritation. Contraction of the pupil in response to corneal irritation is often very striking, showing there is an intimate connection between the filaments of the fifth nerve supplying the cornea and those of the third nerve supplying the sphincter. The sensory orbital reflex arc runs from the cornea to the ciliary ganglion conveying the sensory impulse and is there reflected back to the sphincter pupillæ as a motor impulse. The result is a sharp and excessive contraction of the pupil in case of a jagged cinder in the eye or a crop of phlyctenules. (See *Cramp of the pupil.*)

Trigeminus-facial pupillary reflex. Ballantyne (*Ophthalmoscope,* July, 1909, p. 481) states these reflexes can be elicited in many, if not in most, normal individuals. The reflex is a dilatation of the pupil to a special variety and location of sensory stimulation. Varaday (*Wien. Klin. Woch.,* No. 12, 1903) states that the reaction is elicited by pressing the outer canthus firmly with the end of a lachrymal probe, or pricking the skin of the cheek with a needle for about thirty seconds. By this test "the pupil dilates slowly and completely, then contracts smartly to less than its natural size. If the stimulus is continued the dilatation will return and persist for two minutes and then the pupil slowly contracts. When the stimulation ceases the pupil returns to its original size." The reaction is consensual. Other forms of stimulation such as induced by heat, electricity, etc., may elicit the same symptoms or they may cause pupil contraction with lid closure. The pathway is different in the latter reaction. (See *Sensory pupillary reflex.*)

Tubercle of the choroid. In tubercle of the choroid the pupil was noticed by Clement to be slightly dilated (*Ophth. Record,* Vol. XXI, No. 6, p. 291) but the vision in the disease is usually impaired proportionately with the dilatation of the pupil.

Tubercles at the pupil margin. Schoenberg (*Ophth.,* Vol. XI, No. 1, p. 1) reports the effect of injecting serum from a patient with interstitial keratitis in the ear vein, under the skin and under the conjunctiva of a rabbit. About three weeks later there appeared small tubercles near the lower margin of the pupil. In another rabbit there appeared contracted pupil along with a whitish exudate. When the serum was injected in the cornea of a rabbit severe iritis and occlusion of the pupil set in. Other rabbits showed unmistakable signs of iritis by presenting contracted pupils.

Tuberculosis nodules on the margin of the pupil have been produced experimentally by deSchweinitz and Saxon (*Trans. Sec. on Ophth., Col. of Phys., Phila.,* Oct. 20, 1910) by inserting tubercular tissue from the lower eyelid of a boy who had tuberculosis of the conjunctiva in the anterior chamber of a rabbit's eye. The tubercular bacilli were demonstrated in the nodules present in the pupillary margin.

Tuberculosis of the lung. Pernot examined 1,140 cases of phthisis pulmonalis and found inequality of the pupils present in 6 per cent. of cases in the first stage, 8 per cent. of cases in the second stage and 14 per cent. of patients who had reached the third stage of the disease. The altered pupil was on the side of the greater lesion in the lung. In the first stage the abnormal pupil was dilated, in the second stage sometimes dilated and sometimes contracted, and in the third stage usually contracted. The ultimate contraction of the pupil was explained by the passing over from the state of irritation which caused the dilatation to that of paralysis of the sympathetic which produced the contraction of the pupil.

Fodor (*Wien. med. Wochensch.,* Nov. 11, 1910) reported mydriasis or slow reaction of the pupil in monolateral pulmonary tuberculosis as well as pleuritis, thoracic tumors, aneurysms, etc. The reaction test is best made in a dull light.

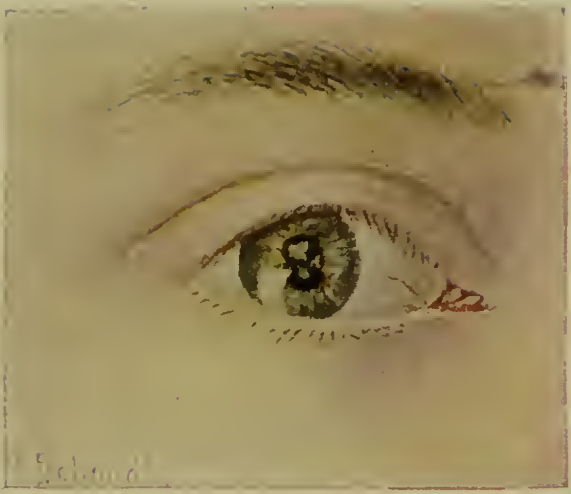
Marich (*Rev. Med. de la Suisse Romande,* Dec., 1906) observed four cases in which pupillary inequality was present in incipient phthisis pulmonalis. There is no doubt whatever about the value of this discovery. The writer observed it in a case that came while preparing this article. A positive diagnosis of acute pulmonary tuberculosis was made by an expert internist. Muralt (*Medizin. Klinik.*, 1913, p. 1814) mentions finding the pupils of different size in about 50 per cent. of cases of pulmonary tuberculosis. The symptom appears early and he regards it of considerable importance in the differential diagnosis. The more dilated pupil is usually on the diseased, or the more diseased, side. He also ascribes the cause to the local irritation of the sympathetic due to inflammatory process in the apex of the lung. The symptom may be constant or it may intermit. (See *Pulmonary lesions.*)

Tumor of corpus quadrigeminum, Diagnosis in. Pupil inequality has been observed from tumor of the corpus quadrigeminum, also occasional absence of convergence reaction and paralysis of accommodation from the same cause. It should be remembered that the inner muscles of the eye may escape in tumor of this region because the position of the nuclei for these muscles is in advance of those for the extraocular muscles, in fact rigidity of the pupils is not a common sign of tumor of this part of the brain.

Hence it is, as reported by Kilisch, Bristowe, Sachs and others, that in tumor of the corpus quadrigeminum, especially in its posterior part, paralysis of the third nerve in all its branches, *excepting* those supplying the intraocular muscles, is found. Sachs also calls attention to the fact that the nuclei controlling the intraocular muscles are at some considerable distance from those governing the extraocular muscles. (See *Diagnosis.*)

Tumors in the pupil area, Occlusion of the pupils from cysts and solid masses. Weeks (*Archiv. of Ophthal.*, Vol. XLIII, No. 5) reports the case of a woman of twenty-eight in whom at the age of eleven pigment masses were seen in the pupils springing from the pupillary margin. The diagnosis was ectropium of the uveal pigment. The vision was somewhat impaired at that time. At the time Weeks saw her, at the age of twenty-eight, the pupils presented the appearance shown in the illustration. The pupil area was entirely occluded by spherical pigment masses varying in size. The tension was normal and the eyeball otherwise unaffected. The transillumination showed these masses were diaphanous. The light projection was normal in each eye. An iridectomy upwards was made which revealed clear lenses presenting no pigment deposits and there were no synechiæ. Attachments to the uveal layer of the iris caused some stripping of that membrane. The vision became 20/20 after the iridectomy. The pigment masses were easily seized with forceps

R. E.



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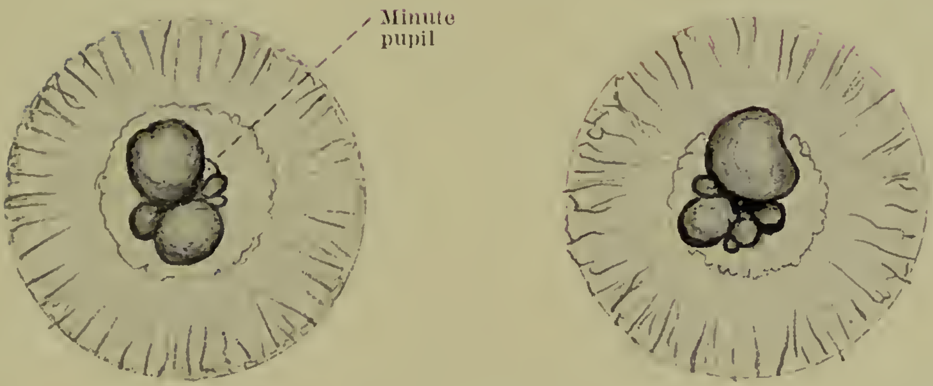

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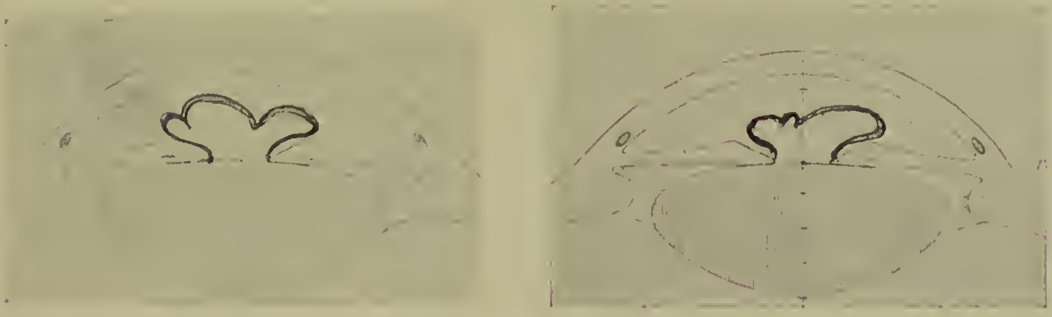


Illustrating a Case of Symmetrical Occlusion of the Pupils by the development of cysts and small solid masses from the uveal layer of the iris.—Weeks, *Arch. of Ophthal.*, Vol. XLIII, No. 5.

and drawn from the eye. The microscopic examination revealed them to be cysts the result of stripping of the pigment layer. Weeks considered the original cysts to be congenital in origin.

Tumor of the pons. Spiller found contracted pupils on the same side as tumor of the pons. "Its presence in four cases shows it is of diagnostic significance and also that the fibers controlling the iris pass through the pons." (See Posey and Spiller, p. 14). The explanation must be that the fibers from the pupil-dilating center in the medulla were paralyzed, resulting in miosis.

Tumor of the optic nerve. When the exophthalmos produced by orbital neoplasm is pronounced enough to cause paralysis of the optic nerve, or when an optic neuroma causes blindness, the pupil does not dilate as long as the other eye is exposed to the light; but when the other eye is in darkness it is found that the pupil dilates and will not react to the light (consensual reaction). This is in conformity with what we would expect and goes to show that in a blind eye, the other eye being normal, the return impulse to the iris from the pupil-centers can be delivered down the pathway to the blind eye the same as in the eye affected, thus showing that the efferent nerves to the sphincter pupillæ are not affected by optic atrophy. If, however, the ciliary ganglion is involved we then find the pupil dilated and non-responsive to any test.

Ulcers of the cornea. In ulcers of the cornea the pupil is usually somewhat contracted. There may be two explanations for this: (1) That the contraction is a reflex defensive effort on the part of the iris from the pain incited by irritation of branches of the fifth nerve supplying the cornea and reflexed from the ciliary ganglion along the motor strands going to the iris, and (2) that the photophobia present in ulcers indicates there is hypersensitiveness of the retina to light and the pupil is therefore contracted. (See *Cramp of the pupil* in this section.)

Ultra-red rays. Reichen (*Zeit. f. Aug.*, January, 1914, p. 20) studying the effect of short-waved ultra-red rays on the eyes of rabbits noted after their use an irritation of the iris and contraction of the pupil lasting several hours. Another observer, Vogt, has recently noted that the iris tissue absorbs ultra-red rays. Excessive absorption, as in the experiment above cited, produces iritis and contracted pupil.

Ultra-violet rays. The pupil may be obstructed by exudations from the iris in cases where there has been a prolonged exposure of the eye to intense light, such as could occur from sun-glare, the electric arc or the mercury vapor lamp, etc. The symptom is usually associated with other more prominent symptoms such as ophthalmia, etc.

Hertel (*Arch. f. Ophth.*, LXV, I, p. 107) conducted experiments on rabbits and cats to see the effect of gas and electric light on eyes that had had the optic nerve severed. It was found that these experiments produced contraction of the pupil while daylight had no effect. The illumination of the iris tissue by this test caused contraction of the pupil from the direct action of ultra-violet rays on the sphincter.

Umbraculum or corpus nigrum. Sisson (*Ophthalmology,* Jan., 1909) discussing in an able paper the effect of intense sunlight on the eyes of man and the lower orders goes deeply into the subject of pigmentation of the vascular structures within the eye. Writing upon the subject of the umbraculum (p. 201) he states that it is an arrangement of the iris into two distinct layers which are particularly well developed in the eyes of the horse and goat. The intensely pigmented inner stratum of the iris is capable of projection into the pupillary space "in much the same manner as an awning is let down in front of a shop window, and for the same purpose." This "corpus nigrum," as best seen in the domestic horse and goat, is projected from the lower pigment layer of the iris and acts as a shield to the retina against glare. It is somewhat thicker and more abundant in the eyes of the wild ass, nodulated in the eyes of goats and gazelles and further elaborated in the eyes of camels, llamas and other such animals that are exposed to intense glare. In the llama it is seen as a series of dentate projections that fit in one another when the pupil is contracted fully. In man we occasionally see small aggregations of pigment at the pupil margin which are described in this section elsewhere under the subject of *Ectropion of uveal pigment.*

Uremia with temporary functional blindness. In the cases of uremia in which sudden and total blindness sets in without ophthalmoscopic lesion being present the pupils react to the light singly and consensually. The blindness is complete but the pupils continue to react. Active purgation and sweating restores the vision promptly. The behavior of the pupils is explained by assuming the blindness to be purely cortical and functional. The pupillary light reflex arc in its afferent and efferent arms reach the pupil-acting center in the corpora quadrigemina and down to the sphincter iridis unbroken in its connection by the functional arrest in the visual areas of the cortex.

Uremic coma. The pupil in uremic coma is always contracted and the two pupils equally so. The response to light is absent or so slight as to pass unnoticed. This is helpful in diagnosing uremic coma as compared with coma from increased cerebral pressure, in which the pupils are widely dilated. But just before death in uremic coma the pupils begin to relax. This indicates paralysis of the brain and oncoming death.

Visual axis in the pupil. The axis of vision, when the patient looks at infinity, is not always exactly in the center of the pupil but very near it. It may be a little to the nasal side of the center but if the patient directs his vision to an object near at hand, as in the act of reading, the axis of vision shifts slightly to the nasal side. These facts have an important bearing on the economic problem of vision in cases of an ulcer in the central region of the cornea.

A scar may be located in the cornea over the middle and outer areas of the pupil and the patient retain good, if not normal, vision, but if the scar is located a little to the nasal side of the center of the pupil it has a very detrimental effect upon the sight. This problem comes up in the surgical treatment of keratoconus by means of the galvano-cautery. It must always be borne in mind that in doing an optical iridectomy the patient will not use the newly-made pupil so long as there is 20/200 vision or better through the scar overlying his natural pupil, no matter how clear the new pupil-space may be. In order to compel the patient to use the newly-made pupil in the act of seeing it is necessary to obliterate the vision through the old pupil by tattooing.

Voluntary dilatation of the pupil. Block (*Deutsche med. Wochen.*, 1906, 31, p. 1237) reports the case of a morphin habitué who had no contraction of the pupils but was able to dilate them at will while the visual axis remained parallel, by simply concentrating his thoughts on dilatation and holding his breath for three or four seconds. The observation speaks in favor of the existence of associated fibers between the cerebral cortex and the dilator center.

Reichardt explained Block's case by assuming that the dilatation accompanied relaxations of the accommodation.

Vossius' ring. Vossius (*Klin. Monat. f. Augen.*, Aug., 1906, p. 566) described a ring deposit on the anterior capsule of the lens resulting from a direct injury to the eyeball. It was only seen after dilating the pupil and examining with a strong lens.

He observed the ring had a brownish color and in some cases it was quite faint. In others it was seen to be made up of fine dots. This deposit disappeared entirely in the course of four weeks, leaving normal vision. He thought the opacity was due to the pupillary margin of the iris being pressed against the lens by the flattened cornea. The brown color he thought was due to iris pigment deposited on the lens capsule. The other grayish opacities he understood to be the result of degenerative changes in the capsullar epithelium similar to the so-called contusion cataract experimentally produced by Schirmer and which was seen to disappear by regeneration of new endothelial capsullar lens cells.

Hoeg held that Vossius' theory is not correct, contending that the pressure of the cornea against the lens does not exist; that the intervening aqueous under compression would rupture the iris. He ascribes the phenomenon to elevation of pressure in the anterior chamber.

Gifford (*Ophthalmology,* Jan., 1909) reported two cases of Vossius' ring in which he observed fine opacities all through the anterior surface of the lens. Other observers have also noted fine opacities in the structure of the lens about the ring deposit. The following year (*Ophth. Record,* August, 1910) he reported another case of Vossius' ring resulting from an injury to the eye of a boy of eleven, which was very plainly made out to be composed of fine points thickly crowded together and many small opacities all through the anterior structure of the lens within and without the ring. The injury was caused by a glancing blow in which the cornea could not have jammed the iris against the lens, according to Vossius' explanation, and so he believes with Hoeg that in this case, at least, the ring phenomenon was due to increased pressure of the aqueous induced by concussion. He refers to the case of Steiner in which a ring was formed from an equatorial injury. The front aspect of the globe received none of the brunt of the blow and yet there was a well-formed Vossius' ring evidently from contra coupe.

Holloway (*Ann. Ophthal.,* Vol. XXI, No. 3, p. 586) cited the case of a boy who had been struck on the left eyeball by a baseball. The pupil was horizontally oval and non-responsive, measured 6x5 mm. and presented no notching of the pupillary margin. A number of punctate opacities were scattered through the anterior layers of the lens and centrally there was a ring-shaped opacity measuring 3 mm. in diameter made up of numerous fine dots. Eleven days after the accident the ring-shaped opacity had disappeared.

Zentmayer, in discussing the case, stated this condition must exist much more frequently than the cases published would seem to indicate for he had seen it three or four times in his own practice and thought it was due to the impact of the pupillary margin upon the lens capsule—a "record" of the pupil margin.

Sweet also reported a case at the same meeting and stated the opacity disappeared in a few weeks' time.

Crampton likewise had a similar case in which the ring-opacity disappeared almost entirely in from three to four weeks.

Zentmayer in closing stated that nine cases of this condition had been reported from the Giessen clinic during a period of six years.

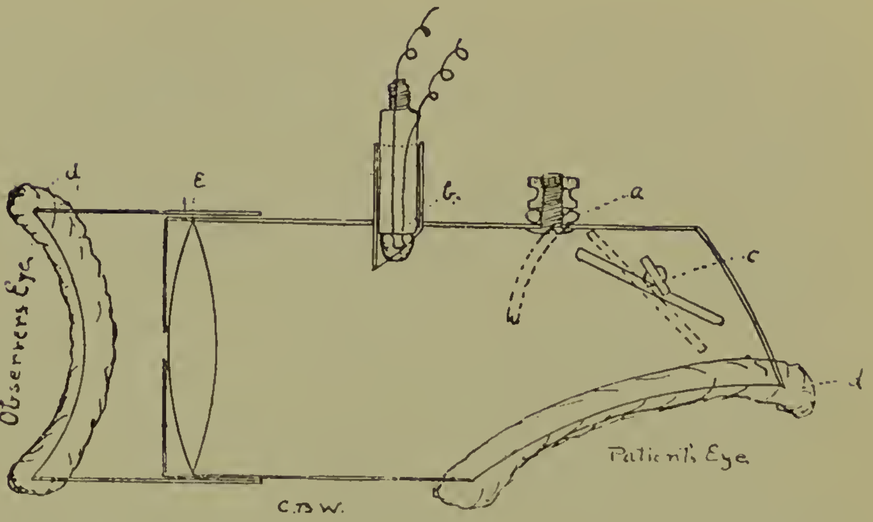
Wandering pupil, Amœba pupil. Erlenmeyer (*Berl. Klin. Wochen.*, XLIX, p. 539) describes a unique case of "wandering" or "amœba" pupil in a woman of forty-two. He mentions the case as being one of hysteric clonic spasm of the iris. There was anesthesia of the cornea and concentric contraction of the field of vision (hysterical). The patient had a distinct aura which contined during the attack. The seizures lasted from ten to twenty seconds and were repeated many times during the day. The vision was blurred while the attack lasted. During the attack the pupil would constantly change its size and shape, the fluctuation being greatest at the inner margin of the pupil (affection of the nasal branch of the sympathetic). The pupil was sometimes vertical, sometimes obliquely oval or again club-shaped; it would spread and twist, become oval and assume eccentric positions. (See *Changing pupil* in this section.)

Weiler's secondary reaction. Carl Weiler (*Zeitsch. f. d. ges. Neurol. u. Psychiat.*, II, p. 2) studied the normal action of the pupil in 84 healthy persons of different ages and found that there was a greater response to slight illumination than was noted in strong illumination. His test consisted in illuminating one pupil and then when both were equally contracted, illuminating the other with the same degree of light. This test revealed an increased miosis of nearly 0.5 mm. He calls this the "secondary reaction" and considers it the total contraction that the central nervous system can produce by a light reflex and predicts that an inference can be drawn from this test in clinical cases which may assist in localizing the cause of pupillary disturbance.

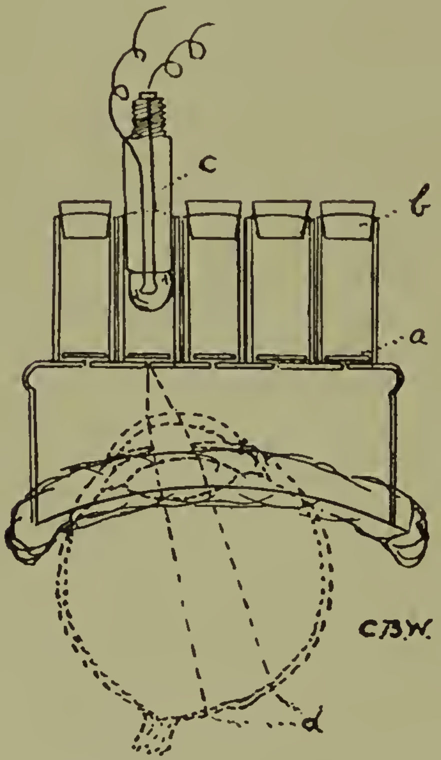
Wernicke's hemiopic pupillary reaction. C. B. Walker (*Jour. A. M. A.*, Sept. 27, 1913) presented a remarkable paper on the subject of "Topical Diagnostic Value of the Hemiopic Pupillary Reaction and the Wilbrand Hemianoptic Prism Phenomenon with a New Method of Performing the Latter." He uses the term "hemiopic" to imply restriction of retinal function and "hemianoptic" to refer to field or visual conditions. From the literature on the subject Walker states the following:

Heddaeus first proposed the diagnostic possibilities of a hemiopic pupillary reaction, but three years later it was popularized by Wernicke and is now spoken of as the "Wernicke reaction."

Heddaeus, in his inaugural dissertation at Halle in 1880, after re-

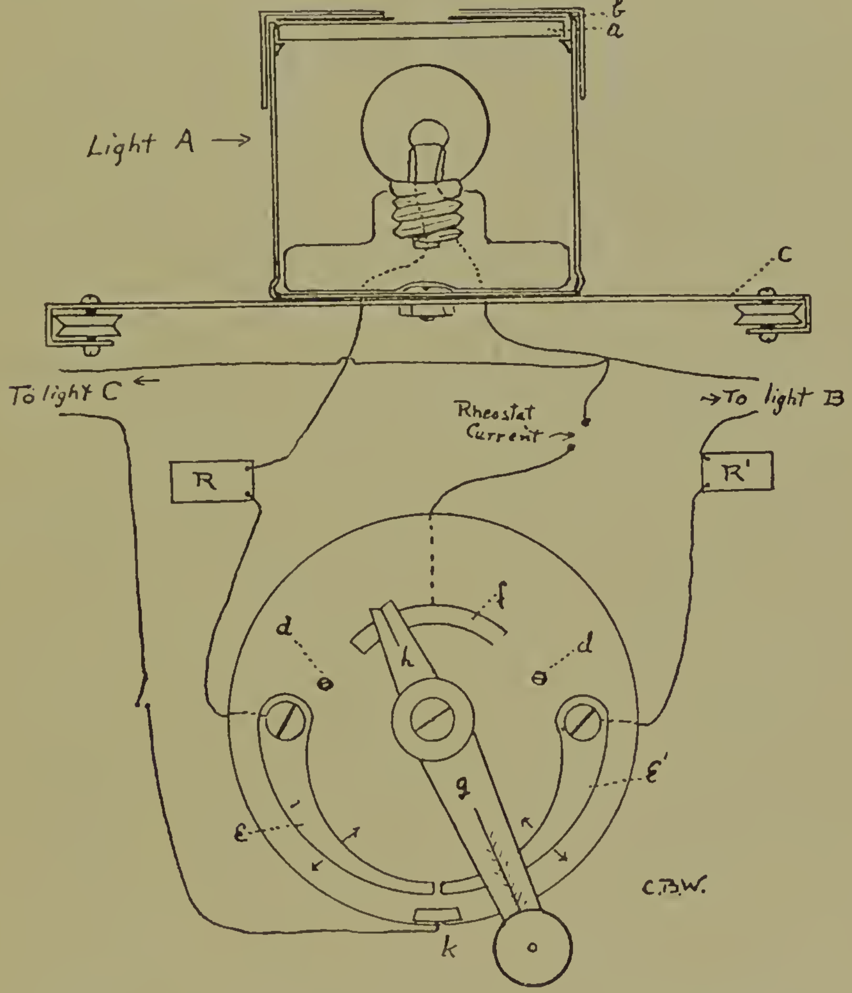


Objective Pupillometer: a, head-spring; b, ophthalmoscope lamp; c, mirror; d, d′, velvet pad; e, 14 D. trial-case lens.



Entopic Pupillometer: a, milk-glass; b, stopper; c, ophthalmoscope lamp; d, dispersion-circle.

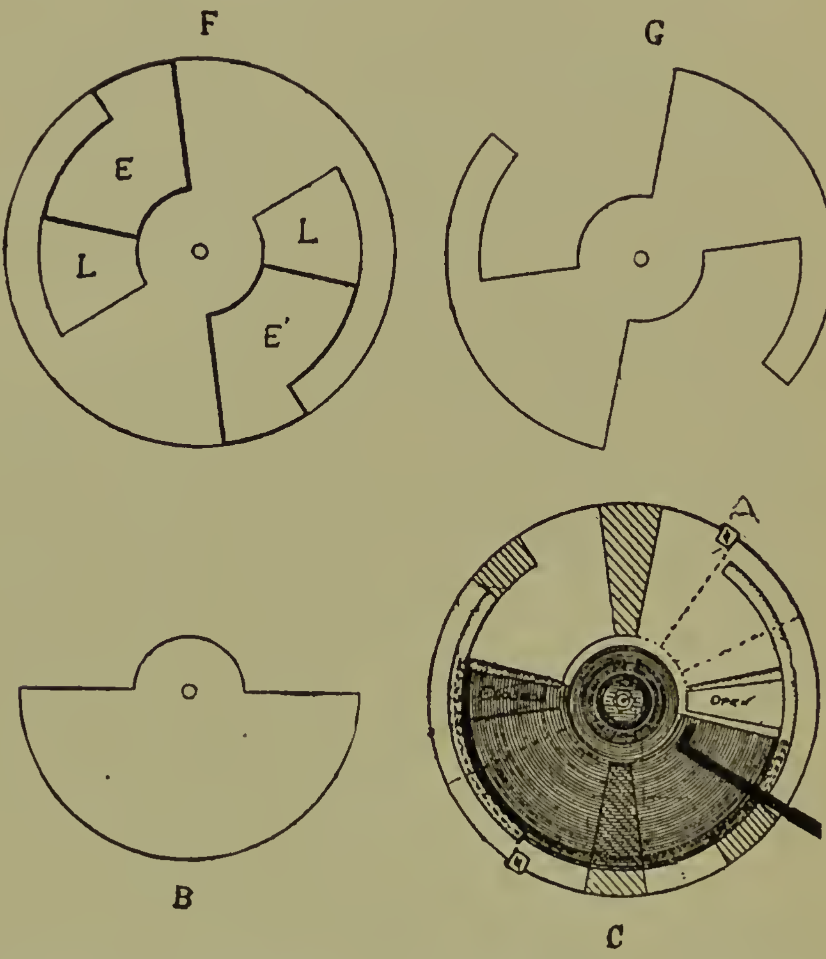
porting his findings as to the pupillomotor relation of blind and seeing retinas, advanced the half-sided or hemiopic pupillary reaction as an aid in determining whether the lesion producing the hemianopsia was central or peripheral to the basal stem ganglia cells and gave one case in which the reaction was observed. Wilbrand in 1881 made a similar proposal.



Test-light Scheme: a, milk-glass; b, diaphragm; c, carriage; R, R′, resistance; e, e′, movable contact-bar; d, d′, stops; f and h, circuit-breaker; g, alternating-switch; k, contact-bar for light C.

In January, 1883, Wernicke published an elaboration of the reaction, mainly on theoretical grounds, as a certain method of locating a hemianoptic lesion anterior or posterior to the corpora quadrigemina, which was considered the sole point of deviation of the pupillary reflex of the oculomotor nerve. Since then the half-sided pupillary reaction of Heddaeus has become known as the "Wernicke reaction."

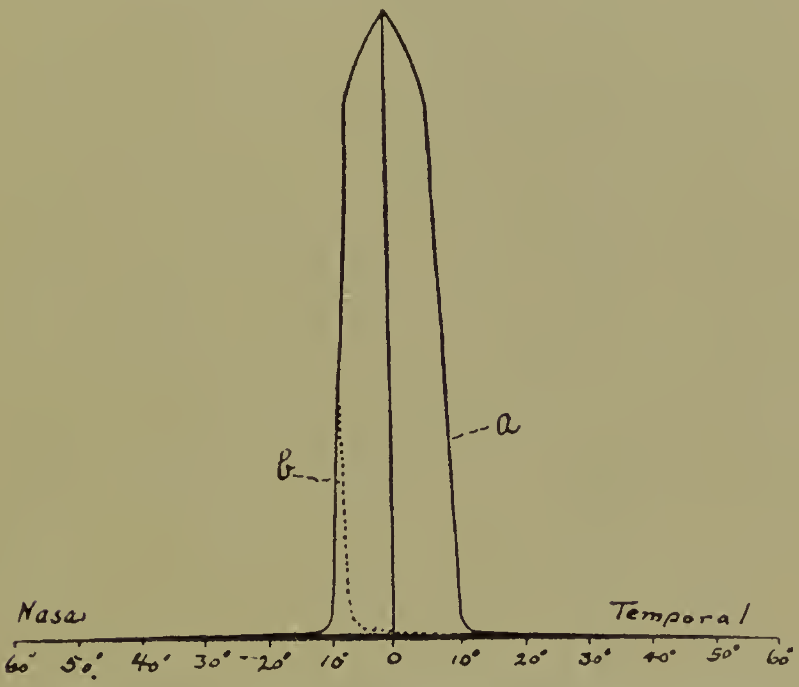
In this reaction it was assumed, (first) that the entire retina was pupillomotoric since it seemed to react promptly to a beam of light thrown on the pupil from any part of the field, though it was known that the macular retina was far more active than the peripheral retina; (second) that pupillomotoric activity persisted in the entire blind area of the retina if the lesion was posterior to the reflex arc, since this was apparently found to be the case in totally blind eyes; (third) that it was possible to stimulate isolated areas of the retina, without materially affecting the macular and other regions.



Plan of Rotary Shutter, Assembled in C from Segments F, G and B, in the position where the equal areas L and L′ are cut down to about one-half full size. A-A′ fixing clamps for holding segments in place.

Further assumption as to the path of the reflex from the optic to the oculomotor nerve was made, which for practical purposes has not since been greatly altered although it has long been the subject of much controversy. In a general way a pupillomotor impulse may be considered to pass from the retina through the optic nerve to the external geniculate body and the pulvinar of the optic thalamus, but more largely to the anterior corpora quadrigemina. From these points they are "relayed" to the nucleus of the third nerve, thence through the third nerve to the ciliary ganglion and then through the short ciliary nerves to the sphincter iridis.

In 1887 Seguin reported three cases of bitemporal hemianopsia with positive Wernicke. The fields were determined on a black-board. A beam of light was thrown on the pupil from the extreme temporal side with very slight or no pupillary reaction. As the light was carried toward the line of vision little reaction was noted until within from 50 to 60 degrees of the line of vision and the reaction was not marked until the center or thereabout was reached, while on the nasal side there was prompt reaction from any point.

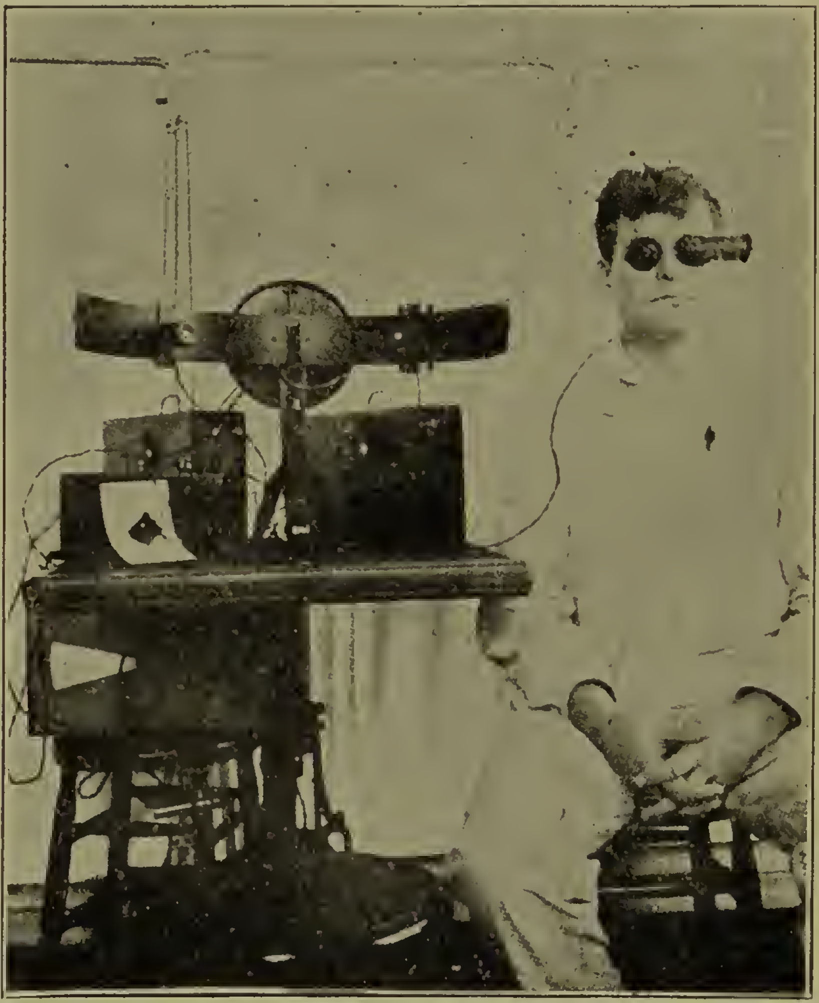


Graphic Representation of Pupillomotor Sensitiveness after Loss of Light-perception: a, curve, showing normal sensitiveness at different points from the center; b, asymmetric progression as failure takes place.

In 1889 Schmidt-Rimpler reported a case of definite cortical lesion with hemianopsia in the right eye resulting from a trauma to the skull. The left eye was previously blind from corneal scars. The hemiopic pupillary reaction was not present at first, but was demonstrable several years after, which fact was explained as being due to secondary degeneration of the right optic tract.

In 1892 Leyden was the first to report a case in which the presence of the hemiopic pupillary reaction had led to the correct diagnosis of the lesion as anterior or peripheral to the corpora quadrigemina, as verified by autopsy.

In spite of the weight of this evidence, Heddaeus, the very next year, regretfully but firmly rejected the "beautiful theory" of hemiopic pupillary reactions and became its first and perhaps strongest opponent up to the time of Hess. He found two cases which led him to change his views. The first case was a superior hemianopsia due to partial retinal embolism in which no difference in pupillary reaction could be obtained from the seeing or blind retina, though the lesion was obviously peripheral. The other case was an inferior hemianopsia with an absolute central scotoma extending 20 degrees into the upper field resulting from a direct injury to the optic nerve. Although good peripheral light perception was present, there was no demonstrable direct pupillary reaction even with reflected sunlight although the consensual reaction from light thrown in the good eye was prompt.



Some of the Arrangements of Apparatus Necessary for Making Tests; the patient has been turned round to face the camera for better exposure.

Heddaeus concluded from this that only the macular region contained pupillomotor fibers and clearly stated that pupillary reaction obtained by illuminating the peripheral retina, in any case, simply represented the stimulation to the macular region by reflected or refracted light and not stimulation from the area of retina illuminated. Accordingly, to keep the amount of dispersion-light striking the macular region as nearly constant as possible in his examination, he originated what was later elaborated by Hess as the "hemikinetic method." In this method two lights of equal intensity were placed equidistant from the fixation-point and from the eye to be examined, the other being blinded with a bandage. When one light was covered at the same instant that the other was exposed, alternately, he found in accordance with his theory no notable change of pupillary size.

Though well founded, these views did not produce many converts. In fact Rothman, the next year (1894) strongly indorsed the hemiopic pupillary reaction test. He reported a case with a central scotoma of 10 degrees, supposed to be due to a tumor of the base of the skull pressing on the optic nerve and still direct pupillary reaction to light was present, though weakened. Further, he found a case of apoplexy with left homonymous hemianopsia and paralysis of the left side with right conjugate deviation. In spite of the latter he believed that he demonstrated the hemiopic pupillary reaction first in the right eye and later in the left. But still later as the paralysis improved the reaction disappeared. From a study of these and other cases he deduced the following possibilities of the hemiopic pupillary reaction: (1) If it is found in an acute case of hemianopsia, the lesion is in the region of the optic tract. (2) If in such a case the reaction later disappears, the lesion was probably in the internal capsule and produced the phenomenon temporarily from a distance. (3) If the reaction does not appear, the lesion is beyond the internal capsule. (4) If the reaction appears in a long-standing hemianopsia, it speaks for degeneration in the optic tract and primary centers. (5) Hemiopic pupillary reaction without hemianopsia means a lesion somewhere between the corpora quadragimina body and sphincter iridis.

Henschen, in 1895, after an examination of pupillary reflex in twenty-six hemianoptic cases, many of which came to autopsy, came to the conclusion that the reaction was present in lesions of the chiasm, the optic nerve and in lesions of the posterior tract and pulvinar of the optic thalamus, but not in lesions of the posterior corpora quadrigemina. The method of examination was the usual single beam of light from small diaphragm.

In the same year Heddaeus pointed out the possible rôle of the psychic or "cortical pupillary reflex" of Haab in elicitation of the hemiopic pupillary reflex. (See *Haab's cortical reflex test* elsewhere in this section.) While Heddaeus was uncertain whether this was a pure cortical reflex or a complicated accommodation reflex, possibly through the acousticus, he was certain that all observations of positive hemiopic pupillary reflexes, from which it could not or had not been excluded, were worthless.

In 1899 Wilbrand, having become convinced that the Wernicke hemiopic pupillary reaction was a practical failure, decided that a new method to the same end was desirable, and proposed his hemianoptic prism phenomenon. With one eye covered the hemianoptic patient was told to concentrate attention on a small white point on a black wall. A strong prism was then suddenly placed before the eye, throwing the image on the blind retina. If the eye instantly moved so as to fix on the point again, the lesion was central; otherwise it was peripheral to the basal stem ganglia. Likewise if the prism was suddenly interposed, throwing the light on the seeing retina, the eye instantly moved to fix the image again; but when the prism was suddenly removed the eye would once more jerk back to fix the point or not according as the lesion was central or peripheral. While he found positive or central cases verified at necropsy, he found no negative or peripheral cases. The test may be made binocularly in homonymous cases.

In the same year further observations were made on both sides of the hemiopic pupillary reaction question. Silex in presenting a case of tumor in the chiasmal region with atypical homonymous hemianopsia, stated that he had no faith in the Wernicke reaction practically because of the physical impossibility of stimulating isolated areas of retina with light without at the same time stimulating the other parts of the same retina. Liebrecht, considering the diagnostic value of the hemiopic pupillary reaction regarded it to stand on a very weak foundation.

Schwartz, on the other hand, from his own experience and on theoretical grounds, actively defended the hemiopic pupillary reaction, contending that these objections were of no importance so long as a difference in pupillary reaction could be obtained from the blind and seeing retina.

In 1901 Vossius actively defended the value of the hemiopic pupillary reaction both theoretically and practically, having found it trustworthy in his own experience. At the same time Hirschberg reported a case with a central scotoma of about 15 degrees, due to optic-nerve trouble, in which there was no direct pupillary reaction whatever, though the consensual reaction was present.

In 1904 Lange reported a most interesting case of complete, sharply-defined, bitemporal hemianopsia of truly traumatic origin. It is the first case on record where a fracture of the base of the skull severed the chiasm sagittally. The hemiopic pupillary reaction was demonstrated by the common method (*vide infra,* with illustration).

Bach in the same year, after an extended study of the pupil in different conditions, stated that he had never seen a pure hemiopic pupillary reaction and considered many positive reports as probably incorrect. (See *Pathology of the pupil* in this section.)

Late in 1906 Bielschowsky examined a case of undoubted chiasmal disease resulting in blindness of the left eye and temporal hemianopsia of the right eye. Although the pupillary reaction is not mentioned, the Wilbrand test was carefully observed in a dark-room. A 40-degree prism was used with a flame for the fixation object. Contrary to expectation, when the image was thrown on the blind retina of the right eye there was prompt motion to refix the object. The patient was an intelligent young girl.

Hess in 1907 introduced an entirely new method of examining the pupillary reflex. (See elsewhere in this section.) He realized, as Heddaeus had previously pointed out, that dispersion light in the eye arising from the refractive surfaces, the transit of the media and reflection from the retina, was a great obstacle in eliciting pupillary reaction purely from isolated parts of the retina, especially with the macular region, as had long been known, much more sensitive than the peripheral retina. Indeed, he found that with the entire cornea carefully covered with a close-fitting black shell in the conjunctival sac, a good pupillary reflex could be obtained in the dark-room by the usual test light from a diffuse illumination of the retina diasclerally. The consensual pupillary reaction was tested by the entopic method, that is, by the eye observing its own pupillary reaction. The eye is covered by a blinder which has a fine pin-point opening a few millimeters from the pupil. This pin-hole is illuminated by a very small electric lamp encapsulated in a light-tight box. The dispersion-circle falling on the retina is seen to vary in size with the pupil, since the pupil determines its size. This method is perhaps the most delicate test for pupillary change in size. Next a modified perimeter with a small pin-hole fixation-point illuminated by an encapsulated electric light and a likewise illuminated milk-glass test object bright enough to give active pupillary reaction was constructed. The test object or light could be regulated as to size, intensity and fixed position on the arc. Hess noted entopically no pupillary change when the test light was moved concentrically with the fixation-point. Further, when the test light, made entirely invisible except for a sheen of dispersion-light, by placing it on the blind spot, it could be moved up or down on to the seeing retina concentric with the fixation point without producing any change in the pupillary size whatever; but any slight movement toward the fixation-point gave a contraction, and motion away from it, a dilatation of the pupil. This was considered proof that the pupillomotoric retina could not be greater in radius than the distance from the blind spot to the macula. By carefully blinding one-half of the retina by looking for one or two minutes at a point on the edge of a large uniformly very bright surface, and then moving the test light back and forth from light to dark-adapted retina concentric with but at varying distance from the fixation-point, it was found that the area of pupillomotoric retina about the macula could be still further restricted to about 4 mm. in diameter. (See *Pupillomotor fibres* in this section.)

In a second communication in 1908 Hess elaborated the double light test. Two equal areas of milk-glass were alternately exposed at equal distance from the fixation-point. These two areas were illuminated equally from behind by the same light. The alternate exposure was effected by a sliding screen with two openings of the same size and shape so placed that during the alternation one area was cut down at exactly the same rate at which the other was increased; thus at all times the total area of illuminated retina was constant and equal to that of one area alone. In this manner the total amount of light entering the eye, as well as the amount of dispersion-light reaching the macula, was at all times constant. Any pupillary reaction must then be due to inequality of pupillomotor sensitiveness of the two peripheral retinal areas stimulated. By use of this method Hess was able to show that the macula itself was the most active point of the pupillomotor region of the retina. Further, that the pupillomotor sensitiveness falls off about the macula in much the same manner as the color sensitiveness—that is, more rapidly temporally on the retina—and can likewise be plotted on a field-chart. Hess examined by this test a case of absolute central scotoma in one eye from nerve disease. Careful measurement of the scotoma corresponded to an area of macular retina 2 mm. in vertical and 4 mm. in horizontal extent. The direct pupillary reaction was barely noticeable even with a strong flashlight, while in the other eye the direct and consensual reaction to the opposite side was prompt even in a very weak light.

A few months later Best reported a case which he considered to argue against the view that the peripheral retina is devoid of pupillomotor sensitiveness. This patient had vision only in the upper temporal quadrant in the left eye. The field did not reach nearer than 10 degrees of the center. The right eye was uninvolved. By testing with a candle moved about on the perimeter, and likewise by reflecting light in the eye from a lamp back of the patient's head, the pupillary reaction was found to correspond to the seeing field and was even found to be less central than in the seeing field. Numerous other minor objections to various points in the work and deductions of Hess were also offered.

In 1909 Hesse repeated the work of Hess, with agreement for the most part, although he could not convince himself that there was absolutely no peripheral retinal pupillomotor sensitiveness. In another experiment he determined relatively the minimal light-strength necessary to produce the pupillary reaction normally, after carefully blinding the macular region out to 10 or 20 degrees he thus found a light-strength which would not give a pupillary reaction centrally but would peripherally. Hesse concluded from these tests that the retina did have a low-grade pupillomotor sensitiveness peripherally, quite useless for diagnostic purposes unless possibly in intelligent patients who could use the entoptic method.

Behr reported a series of twenty cases of hemianopsia. Special attention was given to the hemiopic pupillary reaction and the Wilbrand prism test. There was found no reason to believe that the macula only is pupillomotoric. The hemiopic pupillary reaction was found present in all peripheral cases and absent in all central cases. Although the instruments proposed by Hess were not used, a substitute was used in the form of two fixed electric lights alternately exposed at equal distance from the fixation-point after the method previously used by Heddaeus.

Krusius in 1910 reported a very careful examination of four cases, using an instrument evidently after the hemikenetic or sliding-shutter type of Hess. He concluded that although the hemiopic pupillary reaction might prove of some value, the Wilbrand test was very doubtful.

A few months later Köllner reported the Wilbrand tests on nine cases of homonymous hemianopsia with macular sparing of from 2 to 8 degrees, all presumably of central origin. He agreed with Krusius that the Wilbrand hemiopic prism phenomenon was of doubtful value.

Walker's report on his apparatus and method of performing the hemiopic pupillary reaction. "Figure 1 represents a considerably modified monocular pupillometer after the principle of Krusius. It is held in position over the patient's eye by a brass head-spring attached at a. A rheostated electric ophthalmoscope lamp (b) with frosted globe illuminates the patient's pupil whose image is thrown by the calibrated adjustable laryngoscopic mirror (c) into the observer's eye after being magnified by a 14-D trial case lens (e). All extraneous light is excluded from both eyes by the thick, close-fitting black velvet rim-pads (d). By this means an objective examination of either eye can readily be made without interfering with the field of vision of the other eye.

"In figure 2 is shown the more accurate entoptic apparatus modified from that used by Hess. A considerable improvement for clinical purposes is produced by the addition of several pin-hole openings which can be used at will on either eye to bring the dispersion-circle into the best position for observation, especially when field defects are present. In each case the pin-hole is illuminated through a thin milk-glass or oiled paper (a). The resulting dispersion-circle (d) falling on the retina is limited in size only by the size of the pupil. The apparatus is fixed over the eye, and outside light excluded in the same manner as that described before. With these modifications many more patients are able to use this method. Only average intelligence is necessary.

"Figure 3 shows the form of test-light (A) used. The strength of the light may be varied in the first place by choice from a series of lamps ranging from 2.8 volts to 5.5 volts, tungsten filaments, secondly by resistance (R, R′) connected in series, and thirdly by regulating the ordinary rheostat current by which the electric ophthalmoscope is operated from the house-current, and finally by different sizes of diaphragms (b) thereby varying the area of illuminated milk-glass (a) from any size up to 4 cm. in diameter. This light-capsule is attached to a carrier (c) traveling on an ordinary plain perimeter with arms bent back to form a wider arc (from 20 to 30 cm. radius).

"For isokinetic, hemikinetic and other tests a simple switch and wiring system for controlling two exactly similar lights as desired is provided. The switch has two contact bars (e, e′) movable as indicated by the arrows so that any interval or no interval, with one contact being made before the other is broken, can be obtained by adjustment. In the position shown in figure 3 the current will light B. Moving the switch across the interval lights A and turns off B.

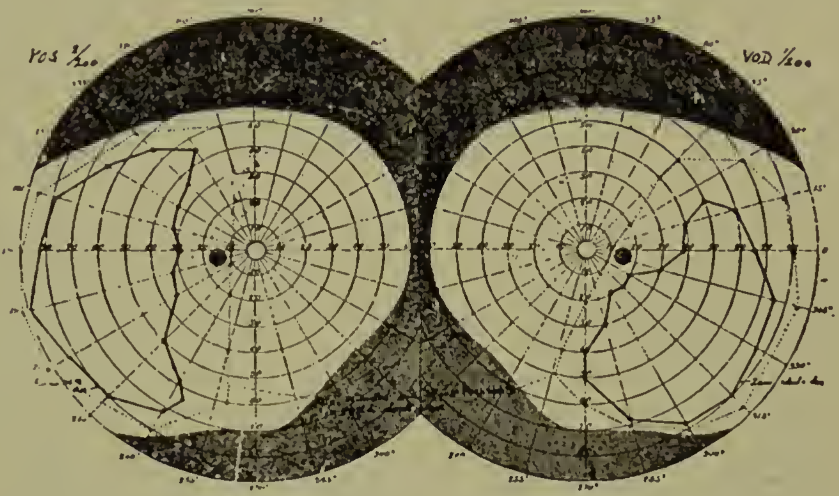
Either light may be turned off without lighting the other by throwing the switch farther over till *h* leaves *f* and strikes either top (d, d′) as the case may be. By means of the resistances (R, R′) two equal lights can be balanced quickly in an ordinary photometric box, and by adjustment of the switch can be made to show no change of intensity in alternate lighting, both in the photometric box and by a further slight adjustment, on the normal pupil by the entopic method. Of course much stronger lights can be used with the same system.

"While this method, when the larger diaphragms are used, is satisfactory, in performing the hemikinetic test of Hess, it is also desirable to have at hand the instrument of shutter-type as described. A different style of shutter which has several advantages is provided. The shutter shown in figure 4 is rotary and not sliding as devised by Hess. This shutter gives a symmetric distribution about the macula, with the weak or peripheral retina receiving the largest part of the image, while the smallest part is nearest the sensitive macula. The shutter works smoothly and accurately and without shaking the instrument, as the sliding shutter of Hess may do. Most important of all, the light in changing is cut off and added in increments situated with absolute symmetry with respect to the macula, while with the sliding shutter during the change light is taken from one side and added to the other side at a different distance from the macula. This will cause a slight reaction at the time of alternation, aside from light adaptation phenomena. A plain shutter of the rotary type having fixed sizes of light surface is easy to make; but considerable and accurately symmetric variation in the size of the light-surfaces without changing the fixation-point may be obtained by use of segments patterned as shown in figure 4. These segments cross in the center, scissor fashion, and make up a disk. Superimposition of segments not crossing the center gives a flat surface on which the semicircular shutter may rotate. A fine hole through the central binding-pin serves as a fixation-point. The shutter is operated by a spring lever as in the ordinary rotary camera-shutter."

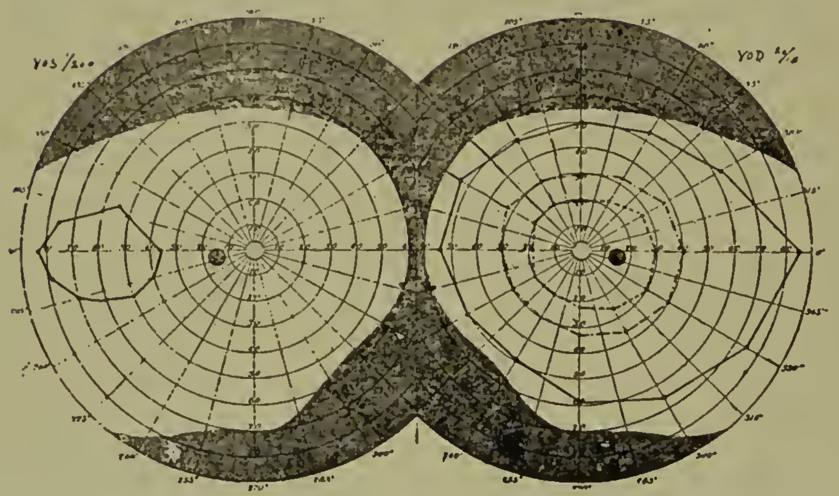
Fig. 5 illustrates the normal pupillomotor sensitiveness according to Hess at different points from the center as represented by the curve (a), as failure takes place it may progress asymmetrically till possibly it may take the curve represented by the dotted line (b) (Fig. 5).

"The photograph shown in figure 6 may serve to give an idea of some of the necessary arrangements of apparatus for making these tests, except of course that the patient has been turned around to face the camera for better exposure."

Walker examined painstakingly twelve cases from the neurologic surgical clinic of Harvey Cushing. As these cases represented types illustrating lesions anterior and posterior to the basal stem ganglia cells the fields taken and the results of the tests (greatly abbreviated) are presented for study and comparison:



Case 1. Fields Taken by Use of Tactile Fixation and Numerous Disks Simultaneously.

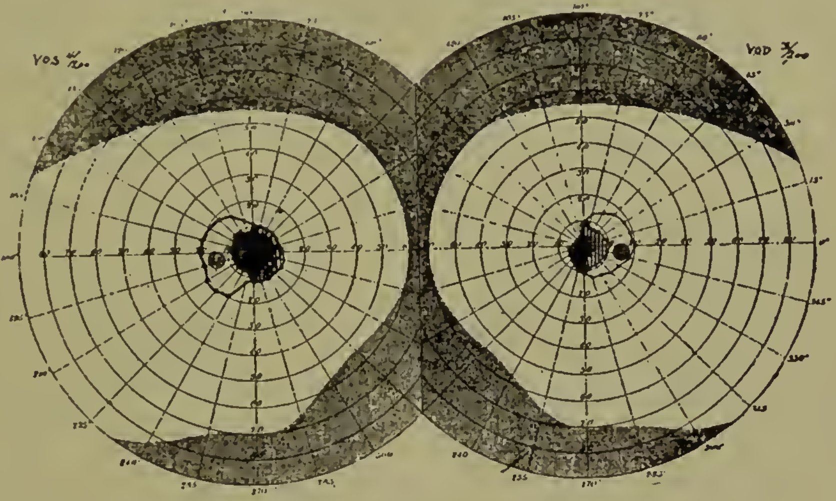


Case 2. Field, Left Eye, Taken by Use of Walker's Combination Blinder and Macular Selector on Right Eye with Proper Allowance for Strabismus; 0.5 cm. Disk.

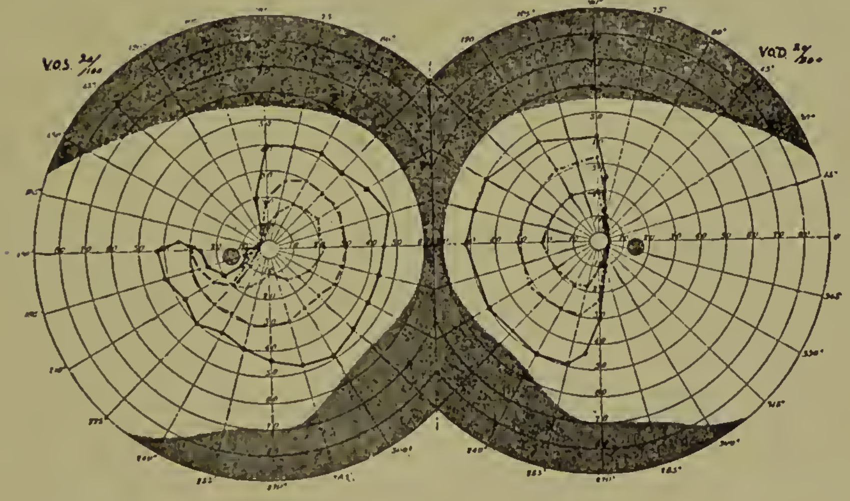
Case I. Familial optic atrophy. Binasal and central blindness. Wernicke present, Wilbrand impossible on account of the nature of the fields (anterior lesion).

Case II. Disease of hypophyseal and pineal glands. All pupillary reactions and tests negative.

Case III. Brain tumor (subtentorial) with papilledema, internal hydrocephalus, etc. Fields: small retained crescentic on bitemporal sides of macula with absolute central scotoma. Wernicke slightly positive. Wilbrand of no value. Other tests indefinite (posterior with secondary anterior lesion).



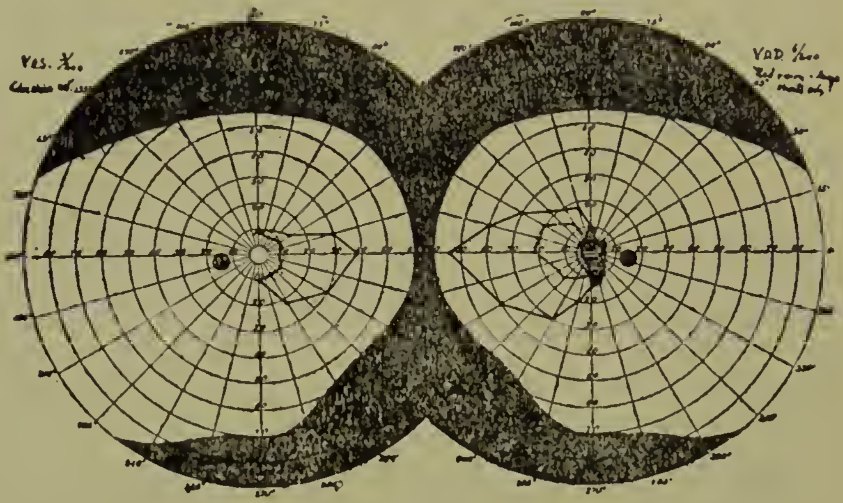
Case 3. 0.5 cm. Disks.



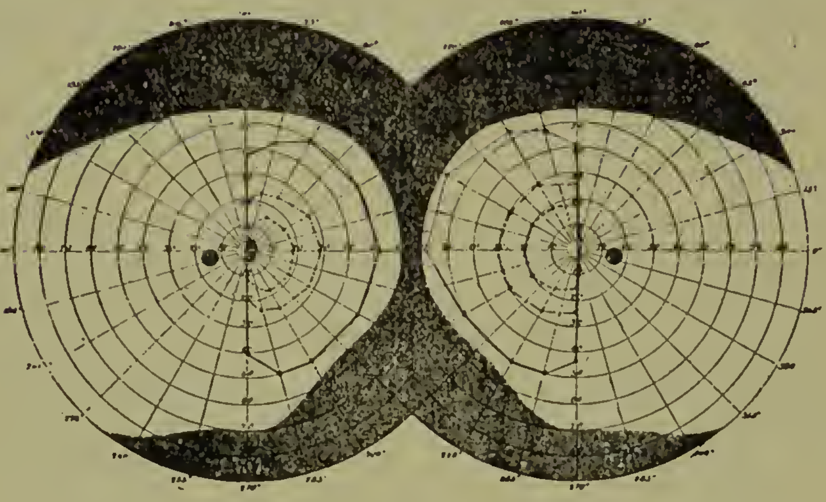
Case 4. 0.5 cm. Disks.

Case IV. Modified bitemporal hemianopsia (hypophyseal). Wernicke negative. Wilbrand positive with left eye, negative with right. (Anterior lesion.)

Case V. Dispituitarism. Complete bitemporal hemianopsia, partial binasal fields retained. Wernicke slightly positive, Wilbrand slightly positive (tardy refixing). (Anterior lesion.)



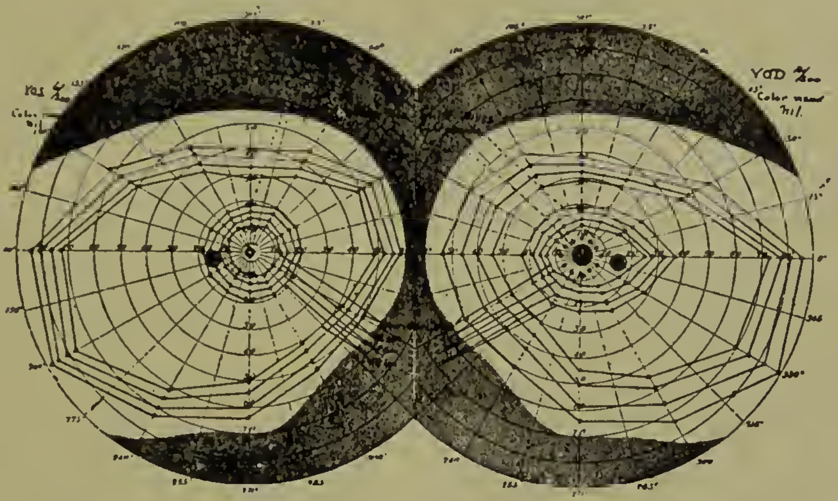
Case 5. 0.5 cm. Disks.



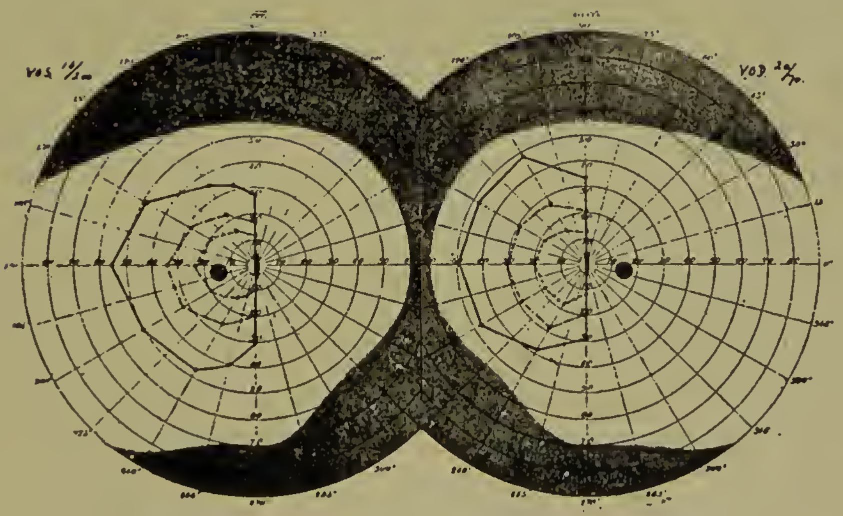
Case 6.

Case VI. Hypophyseal struma. Typical bitemporal hemianopsia. Wernicke entirely negative (no difference on illuminating the blind or seeing side of the retina). Wilbrand negative at first. (Anterior lesion.) (Walker calls attention to the possibility of retained pupillomotoric activity in the presence of absent vision. The latter degeneration preceding the former as has been noted before.)

Case VII. Sphenoidal and posterior ethmoidal disease. Absolute small central scotoma with good periphery. Wernicke negative, pupils react about normally. Wilbrand negative, patient fixes promptly. (Anterior lesion.)



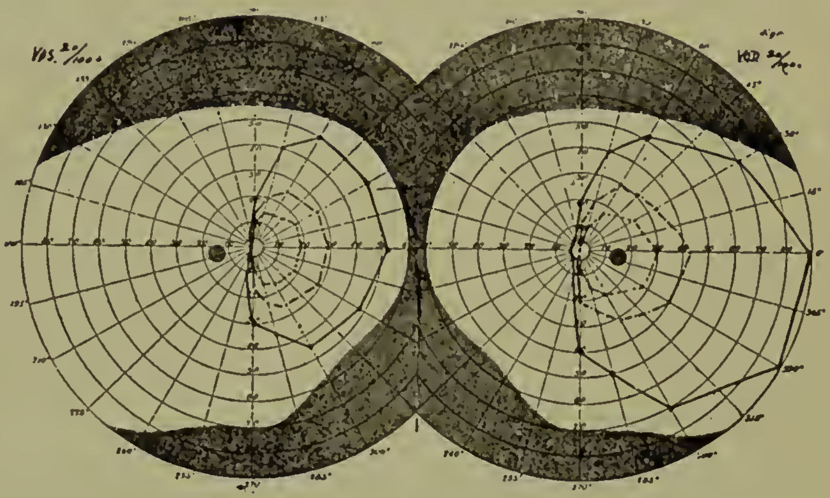
Case 7. Fields Taken More Elaborately, in the Same Manner as in Case 1.



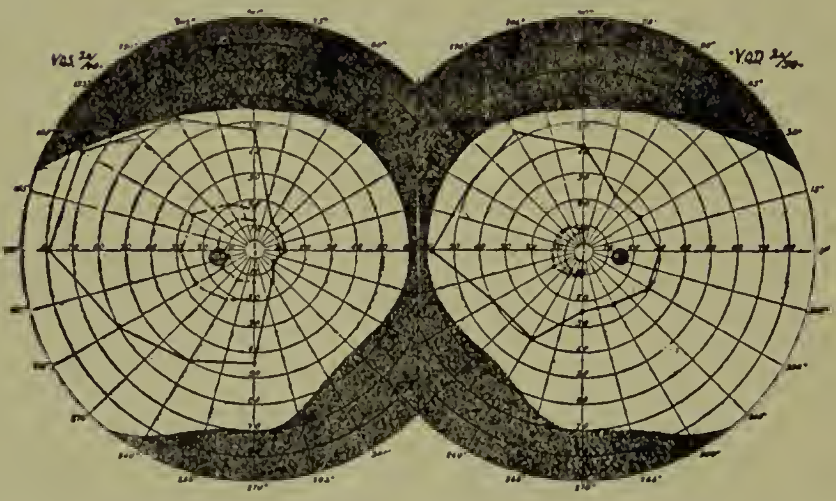
Case 8. ·0.5 cm. Disks.

Case VIII. Hypophyseal tumor extending backwards. (Probably a primary posterior lesion which has extended forward to involve the pituitary.) Fields: Right homonymous hemianopsia rather sharply defined. Wernicke positive by all tests. Wilbrand positive also (could not refix). (Posterior and anterior lesion.)

Case IX. Cerebral hemorrhage. Left homonymous hemianopsia. Wernicke negative by all tests. Wilbrand: slight tardy refixation (posterior lesion).



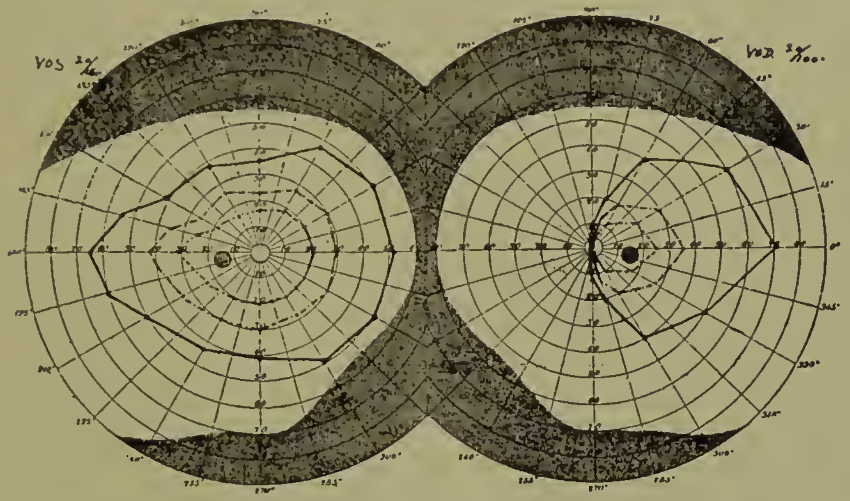
Case 9. 0.5 cm. Disks.



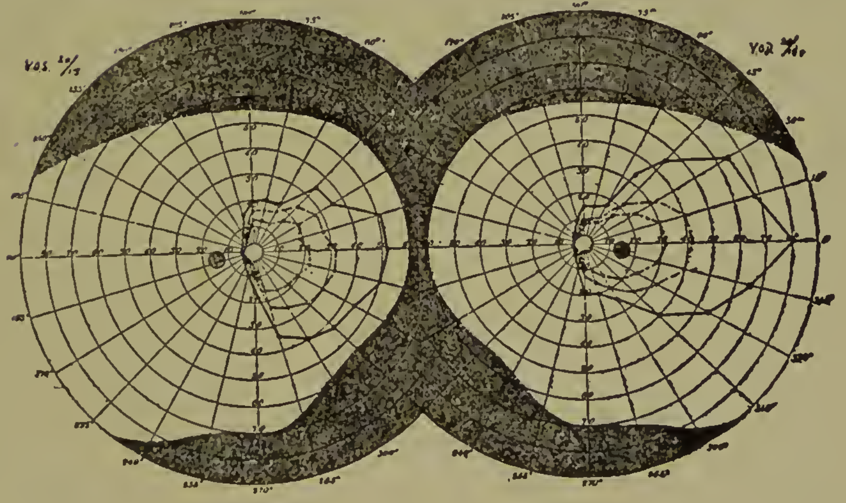
Case 10. 0.5 cm. Disks.

Case X. Tumor right temporal lobe. Right (partial) homonymous hemianopsia. Wernicke negative (pupil reacts from illumination of either the blind or seeing side of the retina). Wilbrand: refixing promptly (posterior lesion).

Case XI. Right frontal lobe tumor (removed). Wernicke negative. Wilbrand entirely negative (would not refix).



Case 11. 0.5 cm. Disks.



Case 12. 0.5 cm. Disks.

Case XII. Cerebral tumor right hemisphere. Wernicke entirely negative (same pupillary reaction from illumination of both sides of the retina). Wilbrand negative (would not refix).

In summarizing the tests and their results Walker offers the following suggestions and conclusions: "From a study of the physiologic and physical difficulties in making hemiopic pupillary tests, certain errors become obvious which have doubtless been common to a large number of reports. These have of couse been chiefly in the use of single beams of light. Thus Seguin in his bitemporal cases carried the light slowly from the temporal side to the center. The pupillary reaction was then so gradual as not to be noted until within 50 to 60 degrees of the center. Now on the nasal or seeing side the light was thrown abruptly over the bridge of the nose, and the reaction noted at once, since it could not be started at 90 but at 60. The obstruction offered by the nose is particularly effective in producing an error in the group of bitemporal hemianopsia in which a hemiopic reaction should theoretically occur. Also the use of the old electric instruments favored variation of the distance of the light-source from the pupil with corresponding pupillary change, there being a tendency again on account of the nose to vary the distance on the nasal and temporal sides.

"The combination Wernicke and Wilbrand test of Heine is open to several errors. If this light is 20 feet distant and strong enough to give a pupillary reaction it will also give a definite sheen of dispersion-light when thrown on the blind retina so that the patient has a cue which way to move the eye. If it is weaker it must be inside of 20 feet, and when the instant loss of fixation occurs the pupil dilates with disaccommodation and contracts again on refixing, owing to accommodation or convergence, as well as to the light itself. Psychic reactions must of course be carefully excluded.

"For clinical purposes in testing for the hemiopic pupillary reaction a rotary hemikinetic shutter of the type described is the instrument of choice, since the openings are more symmetrically arranged and exposed than the sliding types of Hess, are easily regulated and are absolutely alike as to size, though somewhat more difficult to construct properly. Balanced electric lights with a switch as described are more difficult to keep in adjustment, but their use requires no assistant. The presence of a slight reaction or pupillary jump at the instant of alteration in these methods have been considered light-adaptation phenomena. If present at all, the pupillomotor activity of the peripheral retina is so extremely weak that this explanation would not seem to hold. Indeed, when this phenomenon occurs it is usually caused by faulty mechanism or possibly a psychic or psycho-accommodative effect.

"It is notable that failure to elicit hemikinesis has occurred in hypophyseal cases which reached the stage of complete hemianopsia with normal disks only a comparatively short time before examination. That optic atrophy had not progressed far was shown by the rapid recovery after the physiologic or functional block had been removed by operation—in some cases over one-fourth of the temporal field being restored at the first field examination four days after the operation. Possibly, then, the *pupillomotor function in the macular region had not suffered sufficiently to give noticeable hemiopic pupillary reactions.* When the macula is artificially blinded so as to reduce the central pupillomotor activity, not only is the fixation likewise greatly impaired, making the examination very difficult if not impossible, but also the patient is apt to blame any subsequent loss of central vision to this procedure.

"In case the macular region is damaged we have presumptive evidence, when taken in consideration with the form of the field defect, of an anterior lesion since central scotomas are far more common in these lesions than in posterior lesions. The presence of a central scotoma should in addition to its diagnostic value make the examination of hemiopic pupillary reactions easier, owing to the decreased activity of the pupillomotor macular fibers; but on the other hand the difficulty of fixation makes the examination more difficult. If the central scotoma is in one eye only, fixation may be maintained by use of the other eye, but it necessitates the observation of the direct pupillary reaction. If the results are not consistent they are of course valueless. Indeed, the consistency of the results in Case 1 is the only reason for attaching any importance to them. The possibility in this case that the pupillomotor fibers in the macular region may have suffered in a more or less one-sided manner is interesting, but of course not conclusive from the case cited. It is evident, however, that even if the hemiopic pupillary reaction proves demonstrable in this group of cases its usefulness will be very limited indeed.

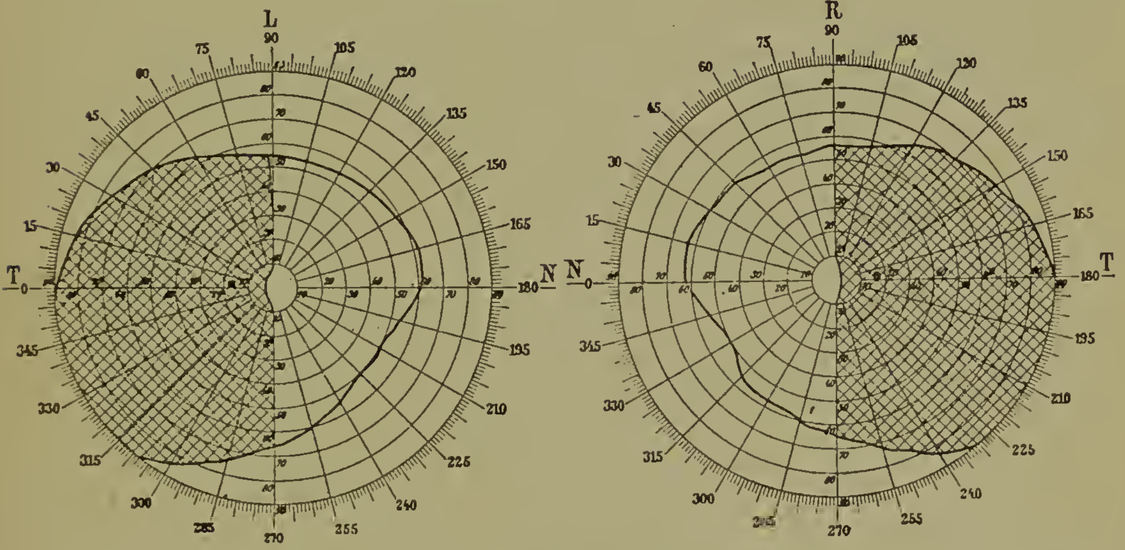
"Concerning the bearing of the presence of pupillary reaction in central scotoma cases on the theory of Heddaeus and of Hess that only the macular region is pupillomotoric, the findings in Case 7 seem to be particularly illuminating. It is at once suggestive of that group of cases reported as having central scotomas but still retaining pupillomotor activity, although the area of central retina involved was greater than that determined by Hess as the pupillomotor area. In such cases it is easy by the use of two or more disks to determine the size of the scotoma; but to locate the position of the macula in the scotoma is not so easy, and in the case of double central scotoma may be practically impossible. It must be remembered then that the macula may be eccentrically situated in the scotoma so that the entire pupillomotor retina is not damaged. Further, it seems that it must be demonstrated that light-perception is nil in the scotoma area although disks cannot be seen to move. To determine the light-perception in a scotoma with a single light is practically impossible since the patient can always detect the light by the sheen of dispersion-light, exactly such as one sees in the darkroom when a beam of light is thrown on the blind spot in the normal eye. In determining these points a new method described in the examination in Case 7 was used, viz.: alternating pupillary lights to get the size of the scotoma for the light and then comparing it with the blind spot. It then became apparent that in all probability the area of absolute central scotoma could not involve the entire area of pupillomotoric retina as measured by Hess. Indeed, as a rule it would seem safe to assume that the best test as to whether a central scotoma of this particular size is absolute or not would be the absence of pupillary light reflex, provided there was no other reason to account for the absence other than the scotoma.''

In a further communication on the same subject a year later (see *Trans. Am. Med. Assn., Ophth. Sec.,* 1914, pp. 318-353) Walker comes to the conclusion that the Wernicke reaction test is definitely present in anterior lesions when examined by the rotary shutter method as well as in posterior lesions; moreover that his series of cases showed that the periphery of the retina possesses pupillomotor sensitiveness. He concludes his paper by stating ''There is no evidence that the hemiopic pupillary reaction has any topical diagnostic value.''

O. Lange (*Ann. Ophthal.*, Oct., 1904) reports in detail a case of bitemporal hemianopsia due to ''dislateratio chiasmatis mediana totalis'' in a boy of twenty years of age who, falling from a roof, struck his right temple against the hard pavement. The examination of his eyes three months later revealed typical clean-cut bitemporal hemianopsia (see fig.) such as could only be produced by sagittal division or disintegration of the chiasm. When the nasal half of each retina was illuminated with a focus of light through a strong convex lens there was scarcely any *pupillary response* but when the same focus was directed on the temple side of the retina the pupil contracted promptly and normally. The analysis of this case as reported by Lange (*loç. cit.*) is worthy of careful perusal. The case illustrates the localizing value of Wernicke's hemianopic pupillary reaction.

Sign positive (that is, the pupil will not contract when blind half of the retina is illuminated) when lesion involves the pupillary light reflex arc, therefore in or below the primary visual centers. (External geniculate body, pulvinar of the optic thalamus and anterior colliculi of the corpora quadrigemina.) *Sign negative,* if the lesion lies *above* the primary visual centers, in the optic radiations or visual cortex although hemianopsia is present.

In hemianopsia if the pupil reacts when the blind side of the retina is illuminated, a differentiation as to the location of the lesion in the cortex or in the optic radiations may be made by observing the presence of some form of blindness, such as word-blindness, mind-blindness, word-deafness or also some form of sensory aphasia such as alexia, dyslexia and paraphasia. These findings in the presence of a negative Wernicke pupil reaction would assist in locating the lesion in or above the optic radiations, but if no form of aphasia or blindness exists, and hemianopsia is present with a positive Wernicke pupil reaction, the lesion may be considered to be below the basal stem ganglia, i. e., somewhere in the optic tract.



Fields of Vision in Bitemporal Hemianopsia from Sagittal Division of the Optic Chiasm (Lange).

Wernicke's pupillary reflex. Max Knies argues that a lesion may exist "so as to interfere with the afferent pupil reflex path between the tract and the third nerve nucleus on one side only, without there being any interruption in the course of the visual path, the result of which would be that on illumination of the different sides of the retina the hemianopic pupil reaction would be obtained without hemianopsia being present." (Knies' pupil symptom.)

Softening of the brain cortex and hemorrhages rarely affect the optic tract, but new-growths and inflammatory lesions do either directly by contiguity or indirectly by increased cerebral pressure, so that Wernicke's pupillary reflex test if carefully applied is of considerable value in determining not only the location of the cerebral lesion but also its general character. Swanzy considers Wernicke's pupillary reaction test of great value, mentions its applicability in those cases of total blindness ("double hemianopsia") in which the pupils react to light in spite of the total amaurosis, proving that the lesion is in the cortex rather than in the optic tracts. (See *Hemianopsia-Knies* in this section.)

Wernicke, Hemianopic pupillary reaction. Van Bouwdyk Bastiaanse (*Tyds. v. Geneesk.*, April 11, 1914) describes the instrument used in the psychiatric clinic at Utrecht. The instrument is made after the principle of Behr. Two electrical lamps are so constructed that one is turned on and the other off at the same switch. The instrument is supplied with electric bulbs of different c. p., and may be used in testing eyes of different irritability.

There is also a devise provided for photographing the pupil. He states there is no question but that the instrument will reveal the location of a lesion in the optic tract from one in the cortex. His method permits an examination of somnolent persons and little children.

Veasey (*Jour. A. M. A.*, Oct. 19, 1907) describes his instrument for conducting Wernicke's hemiopic pupillary reflex test. It consists of a rubber cone in the center of which is a long-focus, convex lens. One end of the rubber tube will fit in the stem of an electric ophthalmoscope or transilluminator. Aberrant rays of light are prevented from entering the pupil.

Westphal-Piltz (Galassi-Gifford) reaction. Antal (*Ungar. Med. Per.*, Feb. 10, 1901) on testing the palpebral reaction of the pupils, ascribed to Westphal-Piltz (Galassi-Gifford), which he recognizes as being two distinct and somewhat different reactions, found in many diseases of the nervous system that the reaction was elicited and also that it was present in many normal individuals. He describes the Westphal reaction as being a contraction .of the pupil noticed when the cyelids are voluntarily and forcibly squeezed together and in which on exposing to the bright light a widening of the pupils was noted (paradoxical). This he calls the "orbicular closure" reaction; while the Piltz reaction is a contraction of the pupil noted when the orbicularis muscle is restrained by the fingers while the patient is attempting to overcome the restraint by making forcible effort to close the eyes; this latter he calls the "orbicularis tension" reaction. In the latter the pupils will also expand when bright light is used (paradoxical).

The *orbicular closure contraction* was found to be present in the following diseases: facial paralysis, progressive muscular atrophy, hemicrania, bulbar paralysis, paralysis agitans, neurasthenia, rheumatism, chorea, chronic gastritis, multiple sclerosis, athetosis, tabes, progressive paralysis, epilepsy, hysteria, Basedow's disease, pavor nocturnus and also in five healthy persons.

The *orbicular tension contraction* (followed by still greater contraction of the pupils and then a slow enlargement) was noted in the following diseases: neurasthenia, rheumatism, hysteria, chronic gastritis, multiple sclerosis, tabes, Basedow's disease, pavor nocturnus, progressive muscular atrophy, and also in five healthy subjects. Both reactions were absent in complete oculomotor paralysis, atropin paralysis, multiple sclerosis, progressive paralysis and tabetic paralysis. From these experiments Antal concludes that both the orbicular closure and the orbicular tension reactions of the pupil are normal and physiological phenomena and are of no special value from a diagnostic sense.

Von Graefe (Graefe's *Archiv.*, Vol. I, p. 318, 1854) clearly described the reaction of the pupil to closure of the lids and practised the test regularly. (See *Galassi-Gifford reaction* in this section.)

Whooping-cough, The pupils in optic neuritis complicating. Gamble (*Arch. of Ophth.*, Vol. XXXII, No. 4) reports a case of optic neuritis complicating whooping-cough in which blindness supervened. The pupils became widely dilated and would not react to light or accommodation.

A case by Greuning is referred to in which the pupils showed the same condition. In another case reported by Gamble in which there was vision 20/15 in each eye. The pupils were dilated and reacted very feebly to the light, but did react to accommodation. In the former cases dilatation of the pupil would seem to be explained by the total blindness, but in the last case some other cause must be looked for. Gamble thinks that there was a localized neuritis incited by the toxins of the whooping-cough upon the interstitial nerve tissue. Intraneural hemorrhage or nuclear hemorrhage induced by the toxin of whooping-cough may produce mydriasis if the sphincter arc is involved, or miosis if the sympathetic tract is implicated.

Width of the pupil. Lans (*Arch. f. Anat. u. Physiol.*, 1900, p. 79) experimented to determine the width of the pupil when accommodation convergence, psychical and sensory excitations were excluded. Snap-shot photographs were taken of the pupil when exposed to absolute darkness for fifteen minutes. The diameter in the subject, aged 29, was 7.8 mm. Abelsdorff experimented to determine the effect of different colored lights on the pupil and found that yellow causes more contraction of the pupil than any of the other colors, but when the pupil is adapted to darkness blue caused the greater contraction.

Lange (*Inaug. Dissert.* Armsterdam, 1901) reports his measurement of 1,000 pupils of persons of different ages and sex. The results were as follows: (1) The size of the pupil differs greatly in different persons. (2) Women have larger pupils than men. (3) The physiological width of the pupil decreases with age. (4) The width of the pupil is less in hyperopia than in emmetropia. (5) The width of the pupil decreases with the degree of hyperopia. (6) The physiological width in myopes is, up to the 20th year, greater than in emmetropia. (7) With increasing age the difference in the size of the pupils with different states of refraction is less marked, and after the age of 40 years it is inconsiderable. (See *Contraction to light and convergence* in this section.)

Wiener and Wolfner pupil reaction in arteriosclerosis and high blood pressure. Wiener and Wolfner (*Trans. Am. Med. Ass'n,* 1915) reported that for the past six years they have observed a condition of the pupil which seemed to be associated with high blood pressure. The pupil in question is slightly dilated, averaging between 4.5 and 5 mm. It reacts promptly to the light, but immediately returns to the original size and remains fixed without the light stimulus being changed.

They state, "It is not claimed that this reaction is pathognomonic of arterial-sclerosis with high blood pressure, but we maintain that it is associated with these states and is so nearly constant as to make it a sign, at least, that it is strongly suggestive and therefore of undoubted clinical value."

They advance the thought that it is possible that the elaboration of epinephrin in exaggerated quantity in the blood stream may cause the increased blood pressure and that since it has a selective effect on the striped muscle fibers of the iris, it may be an influence in causing the pupil to dilate. (See *Arteriosclerosis* in this section.)

Wood alcohol, The effect of, on the pupils. The pupils dilate ad maximum when the fumes of wood alcohol have been inhaled to a poisonous extent, when wood alcohol has been imbibed for intoxicating purposes, or taken inwardly in cheap nostrums. Whether the effect of the poison is directly exerted on the nuclei of the sphincter pupillæ, or whether the pupil dilates because the optic nerve is atrophied, no one has been able to prove. Most likely the pupil dilates because the eyes are blind. The writer has noticed the pupil recover slowly in direct ratio to the return of sight.

Wilder, (*Ophth. Record,* Vol. 3, No. 5) reports a case of wood alcohol blindness in which the right pupil was dilated 8 mm. and did not respond to light and accommodation. The left pupil dilated 5 to 6 mm. and showed faint response to light and accommodation. The vision of the right was nil. The left could count fingers at one foot in the temple field. We note in this case that the response of the pupil was proportionate to the sensibility of the retina.

Worm-like contractions of the sphincter pupillæ (Vermiform or peristaltic movements of the pupil). C. H. Sattler (*Klin. Monats. f. Augen.,* Dec. 1911) as reported by Ballantyne (*Ophthalmoscope,* April, 1913) has noticed very slight movements of the pupillary margin of the iris, progressing from point to point, which he calls "worm-like contractions." They were so slight as to be invisible to the naked eye and were discovered during examination with the binocular loupe. The case in question was a young woman convalescent from influenza. Accommodation was paralyzed. Pupils were inactive, the right slightly larger than the left and not perfectly round. The peculiar movements described were made more frequent and more pronounced by sensory and psychical stimuli. Homatropin abolished the movements, but cocain did not, "thus showing that the sympathetic supply was not involved." Sattler attributes the phenomenon to irritation, probably at the nucleus of the third nerve, and thinks it may be analogous to the fibrillary movements in syringomyelia, due to irritation of motor ganglion cells. It is also suggested that it may be a partial form of hippus, similar to those reported by Bach and Uhthoff in partial recovery from paralysis of the sphincter. Münch (*Klin. Monats. f. Augen.,* June, 1912) in reply to Sattler's communication refers the reader to a communication of his own, abstracted in the *Monatsblätter,* of July, 1907, in which he claims to have described the same phenomenon, taking the view that it was a physiological occurrence. He observed it best in his own eye, using his "pupillenautoskop" for the purpose. He attributes the failure of Sattler and others to find it under normal conditions to the fact that the usual forms of apparatus employed for obtaining a magnified view of the pupil, cast a direct and powerful light into the eye. In his own method, the illumination is weak and lateral, the pupil dilates to about six millimeters and when the retina has become adapted, the movements of pupillary unrest take the form of a peristalsis. This is manifested as a drawing together of the radially disposed iris vessels in a small segment of the pupil margin and a corresponding separation of the radial striæ in the neighboring segments. These changes move from point to point and may even give the impression of a wave travelling more or less completely around the pupil. He has observed the same thing in other normal eyes, but not so well as in his own. This he attributes to the greater difficulty in obtaining the necessary condition of repose. He believes that the phenomenon is physiological and that it can always be found in weak illumination and with the adapted retina.

His explanation of the occurrence is somewhat as follows: The sphincter pupillæ consists of 70 to 80 physiological segments, each of which is supplied by a separate nerve twig. They usually act in a co-ordinated manner, but each has a certain individuality. The length of a "physiological segment" is the same as the average length of a smooth muscle fibre. With a moderately wide pupil, and with the retina adapted to a weak illumination, the independence of the segments referred to is manifested by the conversion of the movements of pupillary unrest into fine localized twitching movements which convey an impression of a worm-like or peristaltic change. When a stronger light stimulus falls upon the eye the strong and rapid response takes the form of an apparently simultaneous contraction of all the segments.

Sattler (*Klin. Monats. f. Augen.*, Sept., 1912) in reply to some of the statements made by Münch in his paper above referred to, states that very slight worm-like movements are sometimes, but not always, to be seen in the normal eye. They are much more easily observed in disease conditions, especially such as are accompanied by a sluggishness or abolition of the pupillary reactions, whether this sluggishness is produced by a central lesion, by a lesion in the conducting path or by a local affection of the iris. The movements, when present, are abolished by atropin and pilocarpin but are unaffected by cocain. In some cases in which the movements were present with deficient activity of the pupillary reflexes, a return or improvement of the latter was accompanied by greater difficulty in observing the abnormal phenomenon. As a rule, the worm-like movements were less noticeable if pupillary unrest was present. They were often more distinct in one part of the sphincter than in others. The nature of the existing stimulus is still unknown. The symptom must be studied with a Zeiss' loupe. He has noticed peristaltic contractions of the pupils in 25 per cent. of his cases of tabes.

Hirschberg (*Zentral. f. Augen.*, Jan., 1912) states "Examination with a loupe (73-year-old-woman presenting this phenomenon) showed thickening of the pupillary margin in two quadrants with movements of the iris making it appear as if a worm were crawling around the pupillary opening.—(D. T. V.)

See, also, **Physiological optics**, p. 9909 Vol. XIII; **Examination of the eye**, p. 4616, Vol. VI; **Pupils, Slit-like**, p. 2855, Vol. IV; and for a consideration of *unilateral mydriasis* see under **Phthisis, Ocular signs of**, in this *Encyclopedia*. The *pupils of the lower animals* are discussed under **Comparative ophthalmology.**

Pupil, Keyhole. A pupil of the shape indicated, formed by a coloboma on the pupillary margin.

Pupillary membrane. PERSISTENT PUPILLARY MEMBRANE. A complete account of the early development and disappearance (at the eighth month of intrauterine life) of the tissue covering the pupil is given under *iris and ciliary body*, p. 3894, Vol. V, while the persistence of this membrane or its remnants is discussed on p. 2839, Vol. IV of this *Encyclopedia.*

Sometimes, also, the term ''pupillary membrane'' is employed to indicate the exudate thrown out in the pupillary area as the result of some form of iritis. See p. 6649, Vol. IX, also illustrations in the section on **Pupil in health and disease** in this volume.

Stähl (*Klin. Monatsbl. f. Augenheilk.*, p. 432, April, 1913) examined 1,600 eyes (800 cases) and found of these 560, i. e., 63.25 per cent., with some kind of remnants of the fetal pupillary membrane. In most of the cases, these remnants consisted of thin, grey, weblike threads, only 8 per cent. showing thicker filaments of the color of the iris. Frequently a grey filament was attached to one or more brown or yellow (more rarely grey) points. Merely punctiform remnants, so-called Schubert's pupillary sand, were found in 432, i. e., 27.6 per cent., out of 1,600 eyes. Hence, this latter finding is the most frequent form of remnants of pupillary membrane. The filamentous remnants were strikingly frequent in both eyes of the same individual and symmetrical with regard to position and arrangement. The greater frequency in younger persons, suggests that even at a later age portions of the remnants are absorbed. They occurred more frequently in myopes and emmetropes than in hypermetropes, and in astigmatism more than in spherical refraction. In agreement with other authors Stähl found more punctiform remnants in eyes with dark brown than with light iris, but the fine cobwebs occurred more frequently in light irides. The remnants were relatively more frequent in the intensely prominent and ragged small circle of the iris, 60 per cent. than in the less developed homogeneous circle, 35 per cent.

A very rare form of this membrane is reported by Terrien and Mawas (*Archives d'Ophtalm.,* July-Aug., 1916; abstracted by Sydney Stephenson, *Ophthalmoscope,* p. 612, Nov., 1916). It was of such dimensions as to reduce sight to between 1/10 and 1/15. The condition, which was roughly symmetrical as regards the two eyes, was treated surgically, and in the result normal vision was obtained.

In order to follow the method of operation adopted by the authors, it should be explained that the membrane, which was not adherent to the anterior capsule of the lens, obstructed the entire pupillary aperture when the pupil was in a state of medium contraction, and was attached to the lesser circle of the iris by a number of fine strands, forming, as it were, so many tendons of insertion, of which some were simple and others ramified (see figures). There were in the right eye twenty-one of these strands, and in the left eye fifteen. It is of interest to note that during contraction of the pupil, the strands became relaxed, and 'allowed the membrane to be displaced forwards towards the cornea, much as a sail might be bellied forward by the wind.

The operation, performed under the influence of 4 per cent. cocaine, was as follows.—An extremely narrow blade, with its cutting edge directed downwards, was passed into the anterior chamber, without allowing the aqueous to escape, through the outer end of the horizontal meridian of the right cornea. The tendons of insertion were then divided as regards the lower half of the membrane by steady saving movements of the blade. As the strands were cut through, the membrane became retracted upwards, revealing a beautiful black pupil. After waiting for about half an hour, during which period the anterior chamber was re-formed, the knife was introduced through the puncture first made, but on this occasion its cutting edge was directed upwards. The attachments of the upper half of the membrane were then divided, the blade being passed for the purpose between the membrane and the anterior surface of the iris. Finally, a section was made at the limbus (the original aperture being utilized for the purpose), and the membrane was removed from the anterior chamber by the aid of iris forceps. Eserine was dropped into the eye, and an occlusive bandage applied. Prior to the operation, the surgeon took the precaution of rendering himself artificially myopic by wearing plus 4 D. spherical lenses.

Sight was not sensibly improved during the first few days, but betterment was noticed on the fifth day after operation, and on the twenty-fifth day it had become normal. This was thought to be due to a progressive education of the macula. The authors regard the V.

of 1/10 to 1/15 before operation as extra-macular, and obtained by slightly inclining the head.

The second eye was operated upon in a similar way, but it was proposed to allow several days to elapse between the two steps of the operation instead of merely half an hour. In point of fact, the second part of the former operation had presented some difficulties on account of the hypotony present, and it was thought that by this modification this might be avoided. But the operation was not completed, due to circumstances over which the authors had no control.

Pupillary zone. The inner of the two zones of the iris.

Pupillenerweiterung. (G.) Mydriasis.

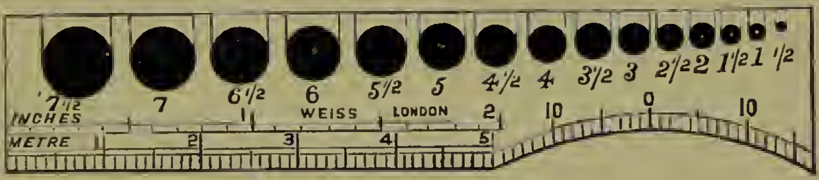
Pupillenfleck. (G.) A round, movable, black spot observed in the pupil of the eye of *Limulus polyphemus.*

Pupillenstarre. (G.) Immobility of the pupil.

Pupillenverengerung. (G.) Contraction of the pupil.

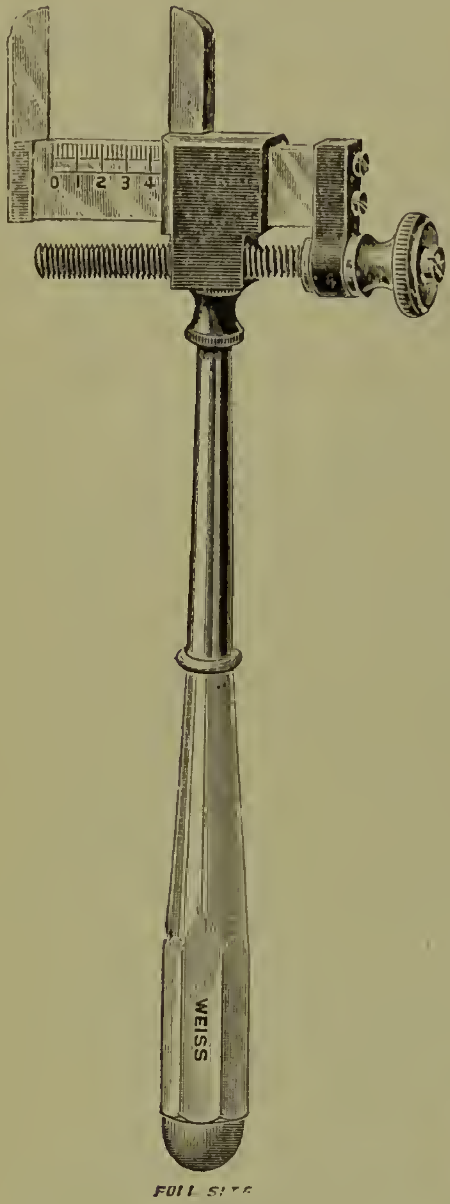
Pupillenversetzung. (G.) Corectopia.

Pupillometer. Numerous instruments (most of them unnecessarily complex) have been devised for measuring the diameter of the pupil, and these are frequently referred and often described in this *Encyclopedia.* Browne's simple and efficient instrument (see Vol. II, p. 1316) is one of the best. See the figure in the text of this caption. A more elaborate one (by Lawrence) is also depicted here, while the well-known instrument of Priestley Smith (see the figure) enables one to estimate the pupillary diameter with sufficient accuracy. See, also, **Pupil in health and disease**; as well as p. 4616, Vol. VI of this *Encyclopedia.*

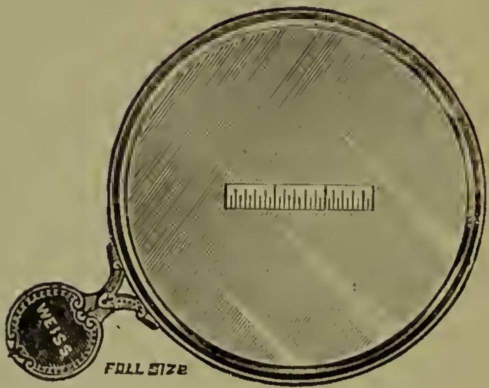


Edgar Browne's Pupillometer.

Finally, a review of the various methods employed in the construction of pupillometers is, with true German verbosity, detailed by Ohm (*Centralb. f. pkt. Augenheilk.,* Aug., 1906). The simplest is measuring with the compass or the comparison with black discs or gauges held near the eye. In the apparatus of Schirmer and Hess (see **Pupilloscope**) the image of the rod measure coincides by means of reflecting mirrors with the plane of the pupil; in those of Dojer and Schadow, the picture of the pupil is thrown upon a scale in a telescope. In those of Galezowski, Dubujadoux and Sommer, two threads are adjusted as tangents to the pupil. The best method, according to the writer, is the photographic, as it fixes the pupil in all its phases. This excepted, all others measure only one pupil at a time. Since, however, the comparison of both pupils is very important for numerous physiologic and pathologic questions, Ohm devised an apparatus in which by means of a system of prisms the images of both pupils are brought side by side and can be measured with great accuracy.



Lawrence's Pupillometer.



Priestley Smith's Pupillometer.

Pupillomotor. Pertaining to the movements of the pupil.

Pupilloscope. With this differential instrument C. Hess (*Arch. f. Ophth.*, 90, p. 382) claims that it is possible to measure the pupillomotor differential sensibility of the human eye, i. e., the minimal differences of intensities of light, which in normal and diseased eyes cause a noticeable change of the width of the pupil. He shows how the apparatus may serve for the investigation of important questions of comparative color vision.

Pupilloscopy. A synonym for retinoscopy, or skiascopy.

Pupillostatometer. An instrument for measuring the distance between the pupils.

Pupil, Paradoxical. See **Paradoxic pupil,** p. 9251, Vol. XII of this *Encyclopedia.*

Pupil reflexes. See under separate captions, and especially under the major heading **Pupil in health and disease.**

Pupil reflexes, Anomalous. Some anomalies of pupillary reaction are difficult to classify. A few of these are here set down; others will be found under various **Pupil** captions, especially under **Pupil in health and disease.** To the matter in these sections may be added the following accounts.

U. S. Bird (*Ophthalmology,* October, 1915) gives the following account of a man, aged 21, with the history of a motorcycle accident about a week previous. Following this he became unconscious, remaining more or less comatose. The only external evidence of injury was a bruise on the right side of the face. The right pupil was said to be dilated. He had pronounced Cheyne-Stokes respiration. On attempting to examine the right fundus Bird noticed that the pupil was at times dilated and then contracted. The fundi were practically negative. The left was normal, while the right showed a cupping at the lower temporal edge of the disk. This, apparently, was not a factor in the pathology under consideration, but suggested a congenital or other independent condition. There was no suggestion of choked disk. The pupillary condition, however, excited his curiosity. Closer observation discovered a rhythm in the contractions and dilations, which was finally associated with the Cheyne-Stokes cycle. The pupils were insensible to light. On the beginning of the labored, snorting inspirations which initiated the Cheyne-Stokes cycle, the pupils began to dilate, reaching a diameter of about 6 mm. in a few seconds. As the force and depth of the inspirations lessened the pupils contracted, until with the practical cessation of respiration they were about 1 mm. wide. How soon after the accident this phenomenon appeared is not known. This patient's skull was opened two hours after Bird saw him, and a clot extending across the base, more on the right, was removed. A permanent dilatation of both pupils is said to have been noted afterward. No bony fracture was found. Three days later he died, two hours after developing a temperature of 108 F. An explanation of this phenomenon may be found by assuming pressure by the clot in or about both carotid canals, compressing the sympathetic fibers against the vessel walls, more or less inhibiting the pupillary function of both nerves. This pressure instead of being constant, the usual condition in intracranial clot, was made intermittent by the effect of the respiratory acts on the intravascular pressure in the carotids, with the pupillary cycle as a result. During the abeyance of respiration the carotid blood-pressure gradually increased to its maximum, increasing pressure being made on the nerve fibers between the vessel walls and the clot, causing approximate total inhibition of the pupillary dilating mechanism, and resulting contraction. On the resumption of violent inspiratory efforts beginning the Cheyne-Stokes cycle, the carotid blood-pressure was reduced, relieving the pressure on the fibers between the vessel walls and the clot, permitting the temporary resumption of the dilating pupillary function. It is hardly probable that the pressure on each side was equal, but the sympathetic functions of the two sides appear to be closely related, accounting for the apparently identical condition of each eye. The post-operative dilation is analogous to that in shock and collapse. In this case it is explained by the evident sympathetic trauma.

In long, continuous and extensive muscular contraction, Redlich (*Practical Med. Series, Eye,* p. 1, 1909) observed maximal pupillary contraction with a loss of reaction to light. No satisfactory explanation of this phenomenon has as yet been given. It is possible that its cause might be found in the changed condition of tension and circulation. If an irritation of the sympathetic were the cause of it we would expect to find the pupil dilated, but the reaction to light would not be lost. Westphal considers the symptom as one of general muscular rigidity.

Van de Graaf (*Ophthalmic Year-Book,* p. 126, 1916) reports the case of a woman 36 years old, with a history of encephalitis in childhood, and later visual hallucinations and psychic disturbance. In the year of the report she developed a series of convulsions, on one occasion forty-three in twenty-four hours. At the beginning of an attack the pupils were dilated, then became contracted and failed to react. Between attacks the pupils were in constant slow hippus. There appeared to be a connection between the pupillary movements and the respirations, the small-sized pupils being associated with deep and accelerated respirations, then after a few seconds when the pupil began to dilate a change in the respirations occurred. Ophthalmoscopically a marked contraction of the arteries occurred just prior to an attack; these vessels could be seen to refill after the attack subsided. At the time of operation the patient was found to have hematoma of the dura in the right frontal region.

Pupil, Slit-shaped. Cat's pupil. Slit-like pupil. See p. 2855, Vol. IV of this *Encyclopedia.*

Pupils, Okew's. A condition in which one of the visual axes is deviated upward and the other downward.

Pupil, Stiff. Argyll Robertson pupil.

Pupil-stop. An ophthalmic "obturator" with a central opening of the size of the normal pupil, for use in determining the refraction of a patient under a cycloplegic. See **Examination of the eye**; also, **Disc, Mason's pupil.**

Pupil test in simulated blindness. See p. 1185, Vol. II of this *Encyclopedia.*

Purblind. Dim-sighted.

Purkinje, Johannes Evangelista von. A celebrated German physiologist of the early 19th century, whose name still lives in the term, "Purkinje-Sanson images." Born at Libochowitz, Dec. 17, 1787, he at first determined to be a priest. At the age of 21, however, he turned his attention to medicine, and, in 1819, at the age of 32, received his medical degree at Prague. His dissertation on this occasion, entitled "Beiträge zur Kentniss des Sehens in Subjectiver Hinsicht," attracted the attention of the scientific world, and brought him the friendship of Goethe.

In 1823 he received the chair of physiology and pathology at Breslau—a position which he held for 26 years. He then moved back to Prague, in order to accept the chair of physiology in the University at that place. Both at Breslau and at Prague he established a Physiologic Institute. He died at Prague, July 28, 1869.

In addition to the graduation dissertation mentioned above, Purkinje wrote, of interest to ophthalmologists:

1. *Commentatio de Examine Physiologico Organi Visus et Systematis Cutanei.* (Breslau, 1823.)

2. *Beobachtungen und Versuche zur Physiologie der Sinnen* (Berlin, 1823-26, 2 vols.).

In the latter work it was that the author announced his great discovery of the three (correctly speaking, two) Purkinje images: The first and second, erect, are reflections from the anterior surfaces of the cornea and the lens, the third, however, inverted, from the forwardly-concave posterior lenticular surface. The first of these images was very well known to the ancients, who, however, believed that it had its origin either on or in the lens, instead of on the cornea. Scheiner was the first to indicate its actual place of origin. Purkinje discovered the other two images, and published his discovery in 1823, together with proper explanations of the origin of these images. For Sanson, however, remained the honor of pointing out, in 1837, the use of all three images for diagnostic purposes—an application which is thoroughly discussed in divers non-historic portions of this *Encyclopedia,* e. g. on p. 6174, Vol. VIII.—(T. H. S.)

Purkinje-Sanson images. See p. 6174, Vol. VIII of this *Encyclopedia.*

Purkinje's (cross-cobweb) figure. The image (shadow) of the retinal blood-vessels of one's own eye, perceived when a concentrated light is directed obliquely into the eye and the source of the light is moved; quite different from the *images of Purkinje,* p. 6174, Vol. VIII of this *Encyclopedia.*

Purple, Visual. RHODOPSIN. This pigment, found in the retinal rods of practically all vertebrates, is confined exclusively to those portions of the retina lying posterior to the equator of the eye. However, the macular rods contain none of this pigment. See **Rhodopsin**; as well as **Boll's retinal purple,** p. 1244, Vol. II of this *Encyclopedia.*

The presence of a pigment in the retina—the visual purple—was suggested by Boll who intended thereby to explain the retinal changes that occur during the visual act.

Purpura. PURPURA HEMORRHAGICA. PURPURA SIMPLEX. PURPURA RHEUMATICA. PELIOSIS RHEUMATICA. SCHONLEIN'S DISEASE. MORBUS MACULOSIS WERLHOFFI. The clinical differences between these different forms of purpura are very artificially constructed. At the bottom of all is an hemorrhagic tendency, a pale, vulnerable skin and anemia. The causes are not defined. Here and there an infectious agent (*bacillus purpuræ Letzerich*) can be accused; in others a ferment intoxication; in others there is a chronic endarteritis with fragility of the vessel walls; in still others the deficiency of blood platelets is put forward as the cause, thus assigning a symptom as the etiological factor. This affection, vulgarly called "the purples," is often also erroneously placed amongst the diseases of the skin. It is in reality, a blood disease, and is characterized by the appearance of small, round spots, of a deep-purple color, which are seen first and most abundantly on the legs, and afterwards extend to the arms and trunk. They are not effaced by pressure, do not rise above the surrounding surface, and are sometimes intermixed with livid patches resembling bruises; and, before disappearing, both the round spots and the patches undergo the same change of color which a bruise undergoes. These spots are not peculiar to the skin, but occasionally occur upon internal surfaces and in the tissues of viscera. There is usually much debility, and often a great tendency to faintness. The duration of the disease varies from a few days to a year or more. Slight cases are devoid of danger, and even the hemorrhagic cases usually recover, unless the bleeding has been excessive or the blood has been extravasated into a vital organ.

The treatment which succeeds best varies in different cases, but the main indication always is to correct the condition of the blood. Arsenic, turpentine, acetate of lead, gallic acid are the drugs which are generally most beneficial; rest in bed, light diet, and laxatives are desirable at the commencement. (*Standard Encyclopedia.*)

The ocular signs of purpura are few. Rarely, the lids are the seat of the hemorrhagic deposits, although hemorrhages into the optic nerve and retina have been noted, as well as optic atrophy.

Motolese (*Ophthalmic Year-Book,* p. 245, 1913) saw bilateral papillitis with alternating convergent strabismus from rheumatoid exanthematous purpura. The patient was a child of 3 years. The day after the onset of febrile symptoms, purpuric patches appeared on the skin of the abdomen and limbs and a convergent strabismus developed. In one eye hemorrhages were associated with the papillitis. With fading of the eruption the symptoms improved.

Péchin reported spontaneous ecchymosis of the conjunctiva of the lids, without ocular complications, in a child 9 years of age, with purpura hemorrhagica. There was a simple anemia which improved considerably under the Roentgen rays.

Purpurescent. Tinged with purple.

Purpurogenous. Producing the visual purple.

Purse-like cataract. See **Cataract, Cystic,** p. 1477, Vol. II of this *Encyclopedia.*

Purslane. PORTULACA OLERACEA. In the times of Pliny and Dioscorides, purslane root was supposed to be injurious to the eyes. Nevertheless, the leaves of purslane, well rubbed up with bean-pods, then mixed with honey and milk, were used as a poultice for *oculi procidentes* (panophthalmitis). Portulaca juice was also esteemed in ulcers of the cornea, while the seed in the form of a poultice was highly recommended by Archigenes for nyctalopia.—(T. H. S.)

Purulent cataract. PUTRID CATARACT. A term (formerly employed) for hypopyon.

Purulent choroiditis. SUPPURATIVE CHOROIDITIS. See p. 2144, Vol. III of this *Encyclopedia.*

Purulent conjunctivitis. PURULENT OPHTHALMIA. An acute inflammation of the conjunctiva, which begins either in the retrotarsal fold or palpebral portion, and is characterized by great swelling, redness, and infiltration of the tissues of the lid, great edema of the conjunctiva, both ocular and palpebral, great heat and pain, some rise of the general temperature, and a profuse, purulent discharge. The complications are ulcer, slough, or abscess of the cornea, prolapse of the iris, and sometimes purulent panophthalmitis. It is markedly contagious by contact with the secretion.

As a recent contribution to this subject, an investigation of infantile conjunctivitis has been carried out by A. W. Williams and C. Rosenberg (*Archives of Ophthal.*, March, 1916) under the auspices of the Bureau of Laboratories of the New York City Health Department in order to determine the present incidence, causes, and results of purulent conjunctivitis in infants under two months of age. Examinations were made of the eyes of 1,000 consecutive births, with the following results: (1) In a thousand consecutive births only 0.8 per cent. had purulent conjunctivitis. (2) In ten cases out of forty-seven cultured cases or in 21.2 per cent. only staphylococcus or staphylococcus and the xerosis bacillus were found, but not in large enough numbers to be considered a cause. (3) In twelve of these cultured cases, or in .25.5 per cent., the gonococcus was found. In nine of these twelve cases, or in 19.1 per cent. only, of all the cases, was the gonococcus found without the presence of either the streptococcus-pneumococcus group or the influenza group of organisms. In three of these twelve cases, or in 6.3 per cent. of all the cases, the gonococcus was associated with either or both the streptococcus-pneumococcus and the influenza groups. (4) In twenty-two out of forty-seven cultured cases, or in 46.3 per cent. of all the cases, was the streptococcus-pneumococcus group of organisms found independent of the presence of the gonococcus and the influenza bacillus. It was thus found to be apparently about twice as often a cause of purulent conjunctivitis as the gonococcus. (5) In twelve cases, or in 25.5 per cent. (the same number of times as gonorrheal infection), was the influenza bacillus group found as the apparent exciting cause. (6) A history of 77 per cent. of cases positively receiving prophylactic treatment, and of a probably greater percentage having received it, suggests the advisability of treatment on the second day with silver nitrate solution. (7) In only three cases was the cornea involved. The fact that these three cases were gonorrheal infections confirms the opinion that cases of purulent conjunctivitis which are infected with this organism are liable to be more severe in infants than those due to other infections. (8) Purulent conjunctivitis in infants is due, in one-third of the cases at least, to organisms other than the gonococcus. (9) The fact that purulent conjunctivitis or ophthalmia neonatorum does not always mean an infection with the gonococcus should make physicians more ready to report such cases to the Health Department. See, also, p. 8511, Vol. XI and p. 3135, Vol. V of this *Encyclopedia.*

Purulent cyclitis. PURULENT IRIDOCYCLITIS. See p. 3622, Vol. V, as well as p. 6603, Vol. IX of this *Encyclopedia.*

Purulent ophthalmia. See **Purulent conjunctivitis.**

Pustular conjunctivitis. CONJUNCTIVITIS PHLYCTENULOSA MALIGNA. See p. 3129, Vol. IV of this *Encyclopedia.*

Pustule, Malignant. See **Bacteriology of the eye**; as well as **Anthrax,**

Put-put. (F.) Datura stramonium.

p. 512, Vol. I, of this *Encyclopedia.*

Putrid cataract. A term formerly employed for hypopyon.

Pyemia, Eye affections due to. Secondary invasions of the whole organism by septic organisms—notably by various strains of streptococci, pneumococci, staphylococci and gonococci, as well as by the typhoid and colon bacilli—may result in purulent depots in any part of the body, including the eye. In those cases where virulent bacteria in quantity pass through the lymph or blood stream into the eye, panophthalmitis generally results. This subject is extensively treated elsewhere—especially under **Panophthalmitis,** p. 9230, Vol. XII, as well as on p. 2146, Vol. III and p. 7672, Vol. X of this *Encyclopedia.*

Pyle, Edwin Wollaston. A well known ophthalmologist, of New York City, who was born in 1849 and who died at his residence in Jersey City, Feb. 7, 1902. He was for some time first assistant surgeon at the New York Eye and Ear Hospital.—(T. H. S.)

Pyocataract. (Obs.) Purulent cataract.

Pyocyanase. This agent is a brownish liquid prepared from broth cultures of the *bacillus pyocyaneus.* (See p. 743, Vol. II of this *Encyclopedia.*)

In a case of serpiginous ulcer of the cornea, in which the process had steadily increased despite energetic medical local treatment, Heilbron (*Prac. Med. Series, Eye,* p. 77, 1910) was able to stay its progress by the instillation of pyocyanase. The active principle of this agent is developed by the formation of a bacterolytic enzyme which acts destructively not only upon cultures of the bacillus pyocyaneus, but upon many pathogenic microörganisms. The pneumococcus was destroyed in 3 minutes.

A. Bronner (*Ophthalmic Record,* p. 192, 1910) described six cases of hypopyon keratitis which he had treated by the local application of pyocyanase from broth cultures of the bacillus pyocyaneus. In all cases the treatment proved strikingly successful, but atropine and hot fomentations had been used in addition to the special application. Bronner considers pyocyanase superior to the cautery or carbolic acid in this class of cases.

Pyoktanin. BLUE PYOKTANIN. METHYL VIOLET. This is one of the numerous aniline dyes that have been used in medicine. It is a blue, crystalline powder, soluble in both water and alcohol and forming with them intensely blue-violet solutions.

Apart from its value as a stain in detecting corneal ulcers and abrasions, the Editor has not found this agent in any of its usual doses (1-100 to 5,000) of particular use in ocular therapy, although Stilling and others have recommended it in various infections of the conjunctiva and cornea—especially in corneal ulcer.

Arning (*Medizinische Klinik,* 1906, No. 4) recommends in the marginal eczema of children a pyoktanin-benzoin varnish prepared by dissolving the required amount of pyoktanin in tincture of benzoin. This procedure is best carried out in an evaporating basin, some of the alcohol being allowed to evaporate so as to obtain a somewhat thicker varnish. This varnish has the advantage of being easy to apply to the edge of the lids by means of a suitable brush; it dries rapidly and adheres firmly. In case a little of the varnish is accidentally allowed to enter the conjunctival sac, it causes a slight burning, but does no harm, for pyoktanin is not irritant to the conjunctiva. If preferred, a thick watery solution of pyoktanin may be used; this also adheres like a varnish.

Wickerkiewicz gives pyoktanin the preference to other remedies in such affections of the eye as gonorrhea of the lachrymal sac, cellulitis of the orbit, and empyema of the cavities that adjoin the orbit.

Pyoktanin has been found very efficacious in corneal ulcer in combination with dionin.

Merck furnishes both blue and yellow pyoktanin in the form of large as well as small pencils, fixed in handles and clasps, for their convenient application to ulcers, sinuses, etc.

In chronic mucopurulent infections of the lachrymal sac H. V. Würdemann employs the following mixture: ℞. Acid, borici, 0.60; Sod. chlor., 0.20; Zinci. chlor., 0.06; Pyoktanin (blue), 0.03; Aquæ dest. 30.00.

J. G. Dorsey uses the following mixture as a collyrium in infections and abrasions of the cornea and as an injection into the lachrymal sac in cases of purulent dacryocystitis: ℞. Methyl violet, gr. ss; Aquæ dest. fl. ℥4.

Pyoktanin, Yellow. Apyonin. Yellow pyoktanin seems to have had as few constant friends as the blue variety, although it, too, has been put forward as a valuable ocular antiseptic, to be employed in the same strength as blue pyoktanin. In the form of pencils it has been favorably spoken of as a germicide when directly applied to ulcer of the cornea and to the lids in the follicular form of trachoma.

Moreover, Blanco (*Archivos de Oftalmologia,* May, 1912) has used and recommends this agent as an antiseptic injection in the treatment of ciliary blepharitis. He employs a one per cent. solution of yellow pyoktanin in distilled water. The syringe needle was inserted at a point two or three millimeters from the external canthus above or below, according as to whether the upper or lower lid was to be injected. The needle was carried through the tissues almost to the internal canthus, parallel with and about two millimeters from the ciliary border. The solution was then gradually discharged from the syringe as the needle was withdrawn, 0.5 ccm. being injected into each lid. For sensitive patients a few drops of four per cent. solution of cocain may be added to the pyoktanin solution. In some cases a single injection produced marked results, while in others several injections were required; but more or less decided benefit was obtained in the large majority of cases of granular blepharitis, with or without ulceration. Success was little or none in squamous, hypertrophic, and seborrheic blepharitis.

Pyophthalmia. Pyophthalmitis. Purulent inflammation of the eye.

Pyorrhea alveolaris, Ocular symptoms of. This subject, which at the moment, is much to the fore in medical literature, has been to some extent discussed under **Dental amblyopia,** p. 3817, Vol. V of this *Encyclopedia.*

As is usual when a new and popular explanation is suggested for a symptom or pathological condition but little understood all sorts of other imperfectly explained morbid states are found to be equally dependent upon the alleged morbific activity. Ten years hence we shall know more positively what ocular symptoms and alterations of eye tissues result from pyorrhea alveolaris. Meantime, it may be further reported that W. M. Beaumont (*Brit. Med. Jour.,* September 26, p. 525, 1913) regards pyorrhea alveolaris as the most frequent source of toxemic iritis, and the reasons would seem to be, first, the great prevalence of pyorrhea, and, second, the fact that the infection in these cases is direct into the circulation, whereas in many other forms of alimentary toxemia the toxins undergo the ordeal of the hepatic furnace.

Again this writer (*British Med. Jour.,* p. 525, Sept. 26, 1914) has investigated the subject of focal infection in the causation of iritis and quotes approvingly Lang's statistics that 64 per cent. of the cases of iritis attributed to sepsis are caused by pyorrhea alveolaris. He is convinced that this disease is undoubtedly the most frequent cause of this form of iritis, although the patient with pyorrhea may also be a sufferer from syphilis or gonorrhea. However, in a patient suffering from this form of eye disease, careful examination should be made of the mouth and, if it is diseased, appropriate treatment should be instituted. Beaumont says that drastic treatment is warranted in these cases, and, if necessary, all foci of disease should be removed by extraction of the offending teeth. As he puts it: "The cure of iritis is of paramount importance, and it is better to lose thirty-two teeth than one eye."

Now that it has been demonstrated that we have in emetine hydrochloride a real specific for pyorrhea, through the use of which we can not only cure the disease, but usually save the teeth at the same time, it is apparent that this alkaloid should be given a thorough trial whenever the iritis is complicated with Riggs' disease. However, the possibility of syphilitic infection should always be kept in mind.

S. G. Tibbles (*Brit. Med. Jour.,* Apr. 4th, 1914) reports two cases of eye conditions associated with pyorrhea alveolaris. The first had vitreous opacties and evidences of a recent choroiditis. The mouth was in bad condition, the gums very unhealthy, teeth carious and broken down. No history of lues. Attention to the mouth was ordered. Mercury and potassium iodid were given internally. In two months the vitreous opacities had cleared and the choroiditis was better. The second patient had irido-cyclitis O. D., keratitis punctata, vitreous opacities and a beginning choroiditis. The mouth showed both gums and teeth to be in a most unhealthy state. Pus oozed from the sockets of the teeth, which were practically all carious. The general condition of the patient was bad. As she had only one eye to depend upon, treatment was urgent. All the teeth were pulled and a mouth wash given. The ocular conditions improved and two months later the eye was perfectly quiet, and treatment was stopped. The health improved and a gain of six pounds in weight was noted.

The *Ophthalmic Year-Book,* p. 135, 1916, also contains a number of observations on this subject. Sedwick reported a case of recurrent iridocyclitis, the cause of which had long remained obscure. The first attack had begun in December, 1911, and was treated successively with sodium salicylate, mercurial inunctions combined with potassium iodid (Wassermann positive), and atropin locally, with but temporary relief. Slow recovery followed the use of a blister on the temple and the administration of salvarsan, but the pupil remained fixed and irregular. A second attack, accompanied by severe pain, occurred in March, 1915. Another attack in October, 1915, was equally resistant to treatment. Examination of the mouth then showed the presence, beneath the gums of such teeth as were not false, of pus which was easily expressed. A case of iridocyclitis of Westcott's improved after tonsillectomy, but had two recurrences promptly because of his effort to save the bad teeth of the patient.

Brown and Irons emphasize the fact that dental infection occurs in a large proportion of all, and care must be exercised in ascribing to such infections a causal rôle when found in subjects of iritis or other metastatic lesions. Alveolar abscesses, or apical infections demonstrated by radiographs and confirmed by the oral surgeon, were found in forty-one out of 100 patients. In eighteen patients the dental lesion was regarded as the source of the iritis. The evidence on which this conclusion was based varied in the several cases but included such facts as the absence of other sources of infection and the prompt clearing of the eye on removal of the cause, or the association of the initial attack or recurrences of iritis with known dental infection; or, if other infectious processes were also present, the failure of treatment to relieve the iritis until the abscesses were discovered and removed. In fifteen patients the iritis seemed to be clearly due to other causes, such as syphilis, tonsillar infection, etc., and the dental infection relatively inactive so far as concerned the causation of metastatic lesions. In the remaining nine patients the dental infection was associated with other infections, often two or more, including tonsillar, sinus, syphilitic, or gonococcal, and the authors were unable to satisfy themselves which infection was responsible for the disease of the eye. So far as possible they tried to arrange the sequence of surgical and other treatment so that they could observe the effect of each procedure on the eye. But in a number of instances considerations of expediency and the saving of vision made it necessary to proceed rapidly to the elimination of all possible causes of the iritis.

That there are no distinguishing peculiarities or marks about an iritis from an apical abscess was demonstrated in a case of iritis of Marple which, put on the usual treatment, began to improve immediately, no attention having been paid to an apical abscess subsequently found. The iritis was soon well, and it was evident that the apical abscess had nothing to do with it. This simply illustrates the importance of being sure that the suspected etiologic factor is the real one and of not forgetting that there may be a combined infection in many of the cases. We may expect to read in our literature for some time to come reports of so-called ocular inflammations dependent on dental infections. Such infections will have a "boom" for a while; but, as Dr. Herman Knapp once said, "We cannot reach a satisfactory conclusion on any subject until its 'boom' has subsided." Then we will probably realize that such infections do play a rôle, but not nearly so important a rôle as seemed to be the case during the "boom."

C. C. Bass and F. M. Johns (*Jour. Am. Med. Assocn.*, Feb. 13, 1915) believe that the ocular symptoms set up by the *Endamœba buccalis* (the bacterial cause of pyorrhea dentalis) as well as the underlying disease can be relieved by hypodermic injections of emetine. This treatment requires to be continued for some considerable period, and relapses can only be prevented by repetition of the treatment until all the lesions have healed. As a supplementary measure they suggest the injection of ipecacuanha or emetine direct into the lesions and also the occasional rinsing of the mouth with fluid extract of ipecacuanha. Whether patients would readily submit to the hypodermic injections of emetine may be doubted, but the other measures might well be tried in view of the failure of most of the present local methods of treatment.

Pyorrhea of Meibomian glands. This name is given to a swelling of the lids due to infection of the glands but without much conjunctival irritation. The course of the gland is marked on the mucous surface by a well-defined line of hyperemia, and a small drop of pus can generally be squeezed out of the glandular mouth on the intermarginal space. Sometimes all the glands on both sides, especially of the upper lid, are involved. The treatment consists in slitting up each infected gland from its opening as far as it seems to be affected, and keeping the wound cleansed by means of an antiseptic solution.

Pyoscope. An instrument devised by Heeren for estimating the richness of milk (in a thin layer between two glasses) by its color.

Pyosis. (Obs.) Hypopyon; pterygium; suppuration of the eye.

Pyraloxin. PYROGALLOL OXIDATUM. ACIDUM PYROGALLICUM OXIDATUM. Pyrogallol oxidized by air in the presence of ammonia. A brown powder, stable in air, soluble in water, especially on warming.

It was introduced into therapeutics by Unna, who has recommended it for chronic conjunctivitis with ciliary blepharitis. He prescribes the following solution for this purpose: ℞ Pyraloxini 0.01—0.05 grm.

(gr. 1-6—5-6); Aquæ boracis (*Aust. Ph.*); Aquæ fœniculi, āā 5 grm. (gr. 75).

By the frequent use of these drops Unna has been able to effect a cure of conjunctivitis in cases which had been given up as incurable.

Pyramidal cataract. A form of cataract resulting from central perforating ulceration of the cornea in early life, and generally associated with central opacity of the cornea. It appears as a small, sharply-defined spot of chalk-white opacity at the anterior pole of the lens, which, when viewed laterally, stands forward as a little nipple or pyramid. It consists of the degenerated products of a localized inflammation just beneath the lens-capsule with the addition of organized lymph deposited on the capsule from the iris. See p. 1574, Vol. III of this *Encyclopedia.*

Pyramidalstaar. (G.) Pyramidal cataract.

Pyretophthalmia. (L.) An old term for an ophthalmia caused by inflammatory fever; fever complicated with ophthalmia.

Pyrheliometer. PYROHELIOMETER. A calorimeter for measuring the heating power of the solar rays.

Pyridin. C_5H_5N. This is a colorless liquid alkaloid with a burning taste and acrid penetrating odor. It is obtained by distillation from bone oils and other organic sources. Taken into the human organism it is changed into methylpyridin and appears under other forms in the urine. It acts as a local irritant to the eyes.

Pyrodin. See **Hydracetin**, p. 6074, Vol. VIII of this *Encyclopedia.*

Pyrogallol oxidatum. See **Pyraloxin.**

Pyrognomic. Exhibiting phosphorescence when heated.

Pyrometer. A high-temperature thermometer, generally constructed without a fluid element.

Pyrometer, Optic. An instrument invented by Becquerel; a photometer used as a pyrometer, the luminous intensity of a body being found to correspond to its temperature.

Pyrophanous. Rendered transparent or translucent by heat.

Pyrophotography. Any photographic process in which heat is used to fix the image.

Pyroscope. An instrument for measuring the thermal intensity of radiation.

Pyrrol tetriodide. See **Iodol**, p. 6571, Vol. IX of this *Encyclopedia.*

Q

Quackery in ophthalmology. See **Charlatan; Popular ophthalmology;** as well as **Ophthalmology, History of**, p. 8524, Vol. XI of this *Encyclopedia.*

Quadrangle. A plane figure having four angles; a quadrilateral.

Quadrant. (a) The quarter of a circle; the arc of a circle containing 90°, or the figure included between this arc and radii drawn from the centre of the circle to each extremity. (b) The navigational instrument better described as the reflecting octant.

Quadrantanopsia. Blindness in one-quarter of the visual field; quadrant amblyopia or defect. See **Military surgery of the eye,** especially p. 7810, Vol. X; **Gunshot wounds of the ocular apparatus,** p. 5666, Vol. VII, and **Hemiopia,** p. 5792, Vol. VIII of this *Encyclopedia.* The subject is also fully treated under **War, Ophthalmic medicine and surgery in.**

Traumatic quadrantanopsia with partial recovery in two cases is recorded by C. E. H. Milner (*Lancet,* July 24, 1915). The occurrence in both of bullet wounds in the occipital region, immediately followed by complete blindness, and of subsequent recovery of vision except in one direction, which was identical in both—the left lower quadrant of the visual field—is noted. And perhaps the chief interest is a psycho-anatomic one, namely, a consideration of the question why there existed a condition of total blindness and why there had been recovery.

As to the etiology of the condition present in both cases, one of double complete hemianopsia passing into double quadrantic hemianopsia, there are two possible solutions: In both cases there was certainly some actual damage done—i. e., some (probably permanent) injury to the lower part of the cuneus on the mesial surface of the right occipital lobe. Such damage would readily account for the persistent quadrantic hemianopsia. It is for the other condition, that of transient double complete hemianopsia, of temporary total blindness, that there are two possible solutions. On the one hand this may have been caused by hemorrhage at the moment of the wound, by blood effused along the mesial aspect of the occipital lobes, which by pressure caused immediate total blindness, and later became organized into a small clot; or it may be due, as suggested by Major F. W. Mott, to a profound but passing shock effect which made itself felt also in the opposite occipital lobe, and for the time being paralyzed the function of the entire visuo-sensory apparatus.

De Lapersonne and Velter (*Ophthalmic Year-Book,* p. 256, 1913) report the case of a youth who was wounded by a revolver bullet, which passed directly from before backward through his left orbit, and was shown to have lodged in the left occipital lobe of the brain near the median line. The right eye was normal, the left greatly protruded. The patient's general condition became so serious as to require two lumbar punctures. The left eye was enucleated, and it was first possible to completely examine the patient sixteen days after the accident. There was marked clouding of the intellect, with disorientation for time and space, and loss of memory. There was visual verbal amnesia, the motor image of the word no longer being evoked by seeing it, but being producible if other sensory impressions came to the assistance of the visual. Examination of the right eye, which had normal visual acuity, showed quadrant anopsia involving the upper temporal quadrant of the visual field, which remained as a permanent defect.

Quadrante astigmatico. (It.) Astigmatic clock-face.

Quadrant hemianopsia. QUADRANT HEMIOPIA. More properly *quadrantanopsia,* (q. v.).

Quadrant of altitude. A graduated quadrant meridionally fixed with respect to an artificial globe.

Quadrant, Polack's. This is one of numerous clock-face devices for the detection and correction of astigmatism. For example, Schots (*Ophthalmic Year-Book,* p. 53, 1913) has constructed a metal quadrant attached to a handle with a circle in the center to which is fastened a movable pointer; the latter is kept constantly vertical by a weight; the cylinder whose axis is sought is attached to the instrument above and a straight line is regarded through it; the instrument is turned until the line becomes straight. The pointer then shows the position of the axis up to 1 degree.

Folinea has found that the Polack movable quadrant having five lines at intervals of 5 degrees favor a more accurate estimate of the astigmatic axis in ten cases than the ordinary clock dial with lines at intervals of 15 degrees. See **Chart.**

Quadrat. An instrument having sights, a plummet, and an index for the approximate measurement of altitudes.

Quadrate. (a) Square. (b) To divide into four equal parts. (c) To square, fit, or agree.

Quadratus. The quadrate muscle. See **Comparative ophthalmology,** p. 2610, Vol. IV of this *Encyclopedia.*

Quadratus, Bulbus. Another name for *phthisis bulbi.* See p. 1327, Vol. II of this *Encyclopedia.*

Quadri, Alessandro. Son of Giovanni Battista Quadri, and a famous Italian ophthalmologist. Born at Naples in 1827, he there received his medical degree, and there, on the death of his father, was made professor of military surgery. He practised chiefly as ophthalmologist, and was a very skilful operator. He died June 27, 1869.

Quadri's chief ophthalmologic writings are as follows:

1. De l'Utilité de la Décoction de Ratanhia dans la Kératite. (*Annal. d'Ocul.*, XXXIII, 1855.)

2. Cas Remarquable de Guérison d'une Fistule lacrymale. (*Ib.*)

3. Recherches et Observations sur les Tubes Cornéens. (*Ib.*)

4. De l'Opération du Staphylôme Partiel de la Cornée. (*Ib.*, XXXIV, 1855.)

5. Mélanges Ophthalmologiques. (*Ib.*, XXXVI, 1856 and XXXVII, 1857.)

6. Compte Rendu des Maladies Oculaires Traitées à l'Hôpital Militaire de la Trinité. (*Ib.*, XL, 1858.)

7. Clinique Ophthalmologique. (*Ib.*, XLII, 1859; XLIV, 1860.)

8. De l'Ophthalmie Militaire dans l'Italie Meridionale. (*Ib.*, XLVI.)—(T. H. S.)

Quadrifarious. QUADRISERIAL. Disposed in four rows or series.

Quadrifocal. Having four foci.

Quadriform. Having a four-fold aspect.

Quadrifrons. Having four faces.

Quadri, Giovanni Battista. Father of Alessandro Quadri, and himself a celebrated Italian ophthalmologist. Born at Vicenza, Italy, in 1780, he devoted himself almost, but, as it seems, not quite, exclusively, to ophthalmology. In 1811 he was prosector at Bologna, but later removed to Naples, where he founded an ophthalmic hospital and became established as a teacher of ophthalmology. He died at Naples near the close of 1851.

In addition to numerous journal articles on ophthalmologic subjects, Quadri wrote "*Annotazioni Pratiche sulle Malattie degli Occhi, Raccolte nella Reale Scuola Clinica di Napoli*" (Naples, 1818-'24, 2 vols.).—(T. H. S.)

Quadriseptate. Having four septa or partitions.

Quadruplex. QUADRUPLICATE. Fourfold.

Quadruple vision. The simultaneous perception of four visual images.

Quaglino, Antonio. A famous Italian ophthalmologist, inventor of sclerotomy for the treatment of glaucoma, founder (1870) of the *Annali di Ottalmologia*, and one of the most distinguished operators of his day. Born in Oct., 1817, at Zubiena, near Biella, in Piedmont, he received his medical degree at Pavia in 1842. In 1843 he was made assistant at the Eye Clinic of Prof. Flarer. In 1849 he became privatdocent for ophthalmology in Milan, and, in 1854, ophthalmologist to the Hospital of the Brothers of Mercy in the same city. In 1860 he won, by competitive examination, the chair of ophthalmology in Pavia, in succession to Flarer. While in this position he became renowned not only as a teacher, but also as operator and writer. Many of the greatest Italian ophthalmologists of today were Quaglino's students. To him it was also due that the most important medical works in German were translated into Italian, those, in particular, of Niemeyer, Virchow, and Stellwag. Late in life Quaglino became completely blind, and, from the time when this occurred, he remained in close retirement. He died, early in the year 1894, aged 76 years.

Quaglino's most important writings are:

1. Dei Progressi dell' Oftalmologia in Italia. (1850.)
2. Commentario sulle Amaurosi Cerebrali, Spinali e Gangliari. (1863.)—(T. H. S.)

Qualimeter. An instrument for measuring the hardness of roentgen rays.

Qualitative. Relating to quality.

Quantimeter. An apparatus for measuring the quantity of roentgen rays generated by a tube.

Quantitative. Pertaining to quantity.

Quaquaversal. Inclined uniformly in all directions from a central point or area.

Quarré, François. A celebrated French ophthalmologist, concerning whom but little is now known. He flourished in the middle and latter half of the 17th century. His fame rests almost exclusively on his having been the first to teach that a cataract is really an opacity of the crystalline lens, and not a ''corrupt humor'' which has collected and inspissated in front of that structure. This latter doctrine had been held and inculcated since at least the Hippocratic period. One does not know definitely whether or not Quarré ever confirmed his theory by anatomical dissection. Rolfinck, however, in 1656, did in that manner undoubtedly and definitely establish the true doctrine concerning the seat and nature of cataract.

Henry Lasnier (we may add for the sake of completeness) as well as Quarré, but a little later (also, presumably, on the same purely theoretical grounds), had declared the intralenticular situation of cataract.—(T. H. S.)

Quarter-square. The fourth part of the square of a number.

Quarter-undulation. A quarter of a wave-length.

Quartilunar. Pertaining to, or consisting of, one-fourth of a lunar month.

Quartz-light. George Coats reviews the work of Mohr and Baumm (*Klin. Monatsbl. f. Augenh.*, May-June, 1911) who by means of a special modification have succeeded in treating trachoma and follicular conjunctivitis with the mercury vapor lamp, a method which has been used in dermatology. For details of the apparatus the original should be consulted. The treatment causes swelling of the lid and the formation of a membrane which is thrown off in about eight days, leaving either a flat or granulating surface, from which the follicles have disappeared. The greatest success is obtained in quite recent trachoma, or in obstinate follicular conjunctivitis. In cases of some standing the results are not much better than with ordinary methods, and in old and deep-seated trachoma they are worse. As the method is costly and the apparatus somewhat formidable one fails to see what place it can have in ocular therapeutics.

Quecksilber. (G.) Mercury.

Quelmaltz, Samuel Theodor. A celebrated Lipsian anatomist, surgeon, pathologist and therapeutist, who should be borne in mind by ophthalmologists in particular and humanity in general, because he was the first to attribute ophthalmia neonatorum to infection. Prior to his time, this terrible disease was ascribed to colds, traumatism, foul air, etc.

Born at Freiburg, Saxony, May 11, 1696, he received his medical degree at Leipsic, and there, beginning in 1737, became, successively, extraordinary professor of anatomy and surgery, professor of anatomy and surgery, professor of pathology and therapy. In 1757 he was elected Dean of the Faculty, and a few months later (Feb. 10, 1758) he died.

He wrote a large number of dissertations, of which most relate to general medicine. The special ophthalmic article is "De Cœcitate Infantum Fluoris Albi Materni ejusque Virulenti Pedisequa" (Lips., 1750). As a matter of course, Quelmaltz knew nothing at all of the germ theory of disease, but, just the same, when he assigned the mother's discharges as the source of the disease in the child's eyes, he had taken a great step forward in ophthalmology.—(T. H. S.)

Querer Durchmesser. (G.) A transverse diameter.

Quetschung. (G.) Contusion.

Quinary. Fivefold; composed of five parts or elements.

Quince. Cydonia vulgaris. In ancient Greco-Roman times, quince leaves, mixed with porridge and wine, were applied to the forehead for any ophthalmic affection accompanied by profuse discharge. For acute inflammations of the eye, the fresh and the dried blossoms of the quince were both highly recommended as a poultice. —(T. H. S.) See **Cydonia.**

Quinia. See **Quinin.**

Quinina. See **Quinin.**

Quinin. Quinina. Chininum. Quinia. Quinine. This alkaloid occurs as a white, flakey powder, with no odor but a persistent, bitter taste. It is sparingly soluble (1—1750) in water: more freely in alcohol and glycerine. The best salt of quinine for ophthalmic use is the hydrochloride (ate), because it is freely soluble in water. The sulphate, citrate, benzoate and borate have also been used.

Quinine is incompatible with ammonia, the alkalies, tannin, iodine and the iodides.

Quinine and its salts have long been employed as a collyrium in various affections of the anterior ocular segment as 1/5 to 1 per cent. solutions but with little benefit. Gonzalez says that a 1 per cent. solution of neutral hydrochlorate (ide) of quinine is of great value in any suppurative infection of the cornea. The remedy produces a burning sensation which rapidly passes off; there is also some lachrymation. He says that the day after the use of quinine the infiltrated zone of the ulcer is less distinct, the abscess becomes smaller and the cornea gradually clears—all due to the antiseptic action of the remedy. Reich-Hollender has advised a lotion and cold compress of the hydrochloride. It is to be used as an adjunct to other treatment, especially after the eye has been irrigated with normal salt solution or some similar fluid: ℞ Quiniæ hydrochlor., 1.00 (gr. xv), Aquæ dest., 90.00 (fl. ℥iii).

As a local application in membranous conjunctivitis Lawson (*Text-book,* p. 538) has the following: ℞ Quiniæ sulph., gr. iv, Acid. sulph. dil., m. ss, Aquæ dest. ad, fl. ʒi.

W. K. Butler, who sees a number of cases of vernal conjunctivitis among the mulattoes of Washington, finds the following mixture of decided value: ℞ Quiniæ hydrochlor., 0.10-0.30, Vaselin. alb., 10.00. This ointment is to be applied once or twice daily.

J. S. Mott advises in corneal ulcer the following collyrium to be dropped into the eye three times daily: ℞ Quiniæ sulph., gr. ii, Atropin. sulph., gr. iii, Glycerini, fl. ʒss, Aquæ dest. ad., fl. ʒiv.

John Tweedy (*British Medical Journal,* Jan. 1, 1916) remarks that he many years ago advocated the treatment of "true" diphtheritic ophthalmia by means of quinine sulphate. For some time past he has employed the sulphate and the hydrochloride salt indifferently, and has extended the method to all cases of infective and sloughing ulcers of the cornea, and to many, if not to all, forms of infective inflammation of the conjunctiva.

Morgenroth and Ginsberg (*Berlin. Klin. Wochenschr.,* p. 2183, Nov. 11, 1912) have elaborated their former work on the effects of the alkaloids of quinin on the cornea, and have tried various strengths of a quinin base in olive oil, from 1 per cent. to 4 per cent. The latter produced complete anesthesia in four minutes, lasting from forty-five minutes to fifty-eight minutes. Hydroquinin base 2 per cent. in olive oil produced immediate anesthesia, lasting from sixty-three minutes to seventy-nine minutes. Ethylhydrocuprein base 4 per cent. in olive oil produced complete anesthesia after one minute, lasting from four to five days; the cornea also became cloudy and the anesthesia was still present to some extent eight days later. They also tried isopropylhydrocuprein base and isoamylhydrocuprein base. The principal result shown is that ethylhydrocuprein-hydrochlorate, in a solution of erythrocytes, is much more soluble and absorbed much quicker than in oily solution.

Leber (*Bericht der Ophthalm. Gesellschaft,* 1913) tried the effect of a 1 per cent. solution of quinine upon trachoma in Sumatra. It appeared to diminish the subjective sensations, but had no real effect upon the disease. The cell inclusions, however, lost their outline and degenerated. He also tried an oily solution of a derivative of hydroquinine, ethylhydrocuprein, upon hypopyon-ulcers. Some were favorably influenced, but others progressed uninfluenced by the drug. In the discussion that followed, Löhlein said that there was no evidence that the cell inclusions were the cause of trachoma, and Leber's observation that quinine destroyed these inclusions, but did not influence the disease, strengthened the conclusion. Experiments had shown that quinine had no influence upon trachoma. See, also, **Quinin amblyopia.**

Quinin amblyopia. QUININ BLINDNESS. QUININ AMAUROSIS. AMBLYOPIA FROM CINCHONISM. Partial or complete blindness due to general poisoning by quinin or other derivatives of cinchona bark. While this condition is called quinin-blindness, it may be caused by any of the alkaloids found in cinchona or may result from a large dose of the tincture of the bark. The sulphate and bisulphate of quinin are more active than other salts. Owing to the fact that in most of the cases the patients were suffering from general diseases—such as malaria, syphilis, meningitis, pneumonia, typhoid fever, gastro-enteritis, etc.—it has been doubted that the blindness was due to the ingestion of quinin. On the other hand, the exact clinical picture of quinin-amaurosis can be produced in dogs.

The dose causing blindness has varied from 15 grains to 1 ounce in twenty-four hours. Occasionally temporary blindness has appeared after the administration of 15 grains in divided doses in twenty-four hours. Of 69 cases gathered from literature by de Schweinitz, 42 were males, 20 females, and in 7 the sex was not given. The ages varied from 3 to 65 years. Thirty-four were under 40 years of age. One case is recorded in which a negro became blind from quinin.

The symptoms of quinin-amaurosis are: 1. Total blindness following the ingestion of large quantities of quinin. 2. Contraction of the visual fields. 3. Marked contraction of the retinal blood-vessels. 4. Pallor of the optic discs.

The pupils are widely dilated and do not contract on exposure to light; but, according to some observers, they contract to a slight extent on accommodative effort. This was true of a patient seen by the author. Erythropsia has been observed in one case.

To explain the occurrence of this type of amaurosis we must look to the vasomotor system. In dogs poisoned by quinin de Schweinitz found thickening and changes in the walls of the optic-nerve vessels (endovasculitis), thrombosis of the central artery with organization of the clot, and complete atrophy of the visual tracts. Holden has shown that the toxic effect is exerted primarily upon the ganglion-cells of the retina.

Quinin amaurosis might be mistaken for embolism or thrombosis of the retinal vessels. These affections are unilateral, while quinin-amaurosis is almost always bilateral.

Prognosis is favorable so far as the restoration of central vision is concerned. In grave cases the visual field is not restored in its entirety. In one instance the patient was practically blind two years after the administration of quinin, vision in the better eye being equal to perception of movements of the hand at six feet. It is probable that other cases equally unfortunate have occurred, but have not been reported.

In treatment the drug should be discontinued. The patient should be placed in the recumbent position. He should be fed with nutritious substances, such as beef-broth, soups, etc. Inhalations of nitrite of amyl can be cautiously tried. Strychnin should be used by the mouth or hypodermically.—(J. M. B.)

The following abstracts from the literature to date (1919) further exemplify the various aspects of this subject.

Seeligsohn (*Berlin. klin. Woch.,* ix, 1907) reports the case of a delicate, anemic woman, aged 36, who was in the habit of taking from one-half to one gram of quinin for nervous headaches. After using 6 grams within three days, of which 3 grams were taken on the last day, the patient experienced, the next morning on rising, intense tinnitus, vertigo, tremor, and was totally blind and deaf. While the hearing returned after 24 hours, only a slight perception of light was first noticeable 10 days later, and vision was not restored completely until after two months. The pupils showed maximal dilatation. The fundus presented the aspect of embolism of the central retinal artery, diffuse whitish opacity of the retina, red spots at the macula, narrowing of the blood-vessels, indistinct borders of the discs. Gradually the discs became pale, and finally atrophic, the blood-vessels had whitish sheaths, the blood column was very much attenuated, while others were obliterated and transformed into white streaks.

After three years the choroidal vessels appeared sclerotic. The visual field was concentrically contracted and formed a horizontal fissure. It beame normal for white after two months, whereas the distinction of colors was permanently impaired. The pupillary reaction to light and on convergence, at first abolished, became gradually normal, but again decreased within the last year.

Although the rabbit's eye is quite unlike the human organ and laboratory experiments on the former afford little practical information so far as human pathology is concerned, it is as well to consider a few of these. For example, Emil Behse (Graefe's *Archiv für Ophthal.*, 70, 2, 1909; review in the *Oph. Review,* p. 301, Oct., 1909) conducted a series of experiments on rabbits, injecting subcutaneously a solution of quinin bichloride. The fundus was examined by means of Schulter's ophthalmoscope.

In most cases the usual pallor of the disc and narrowing of the vessels, especially the arteries, were readily induced; but considerable differences were observed in the dosage of the drug necessary to produce these changes in different animals of apparently similar character. This corresponds with the fact of idiosyncrasy observed in the human subject. Details are given of the microscepic examination of the eyes obtained from the animals treated. Briefly, it was found that when clinically the contracted arteries recovered their normal calibre no organic changes were noted on microscopic examination. In other cases with persistent contraction of the vessels, this was found to be the result of spastic contraction. In the severest cases there were actual changes in the vessel walls involving any or all of the coats, thromboses (especially in the central artery where it entered the stem of the optic nerve), and chromatolysis of the ganglion cells and the cells of the inner nuclear layer.

The author believes that the poison acts first on the vessels directly, producing a spastic contraction. This may pass off with more or less complete recovery of function, or it may persist and lead to actual organic changes in the vessel walls.

He is not prepared to express an opinion as to whether the changes in the retinal cells result from a direct toxic effect or from malnutrition secondary to the vessel changes.

Cargill (*Ophthal. Review*, p. 91, March, 1909) reports E. M., female, aged 28, whose sight had failed 9 months previously after taking ʒi of quinine sulphate; it was accompanied by severe tinnitus, deafness, and giddiness. The vision gradually improved to 6/9 in one eye and 6/12 in the other. The irides acted to central illumination only, the discs were pale, and the vessels small.

Carl Williams's (*Oph. Year-Book*, p. 249, 1909) case of quinin amaurosis occurred in a young woman, who took 80 grains of quinin, which caused stupor, nausea, vomiting and blindness. Vision gradually returned, and two years later was 6/9 in each eye; marked contraction of the visual fields; light-sense reduced to 3/10 (de Wecker's scale) in each eye; the discs were gray and the retinal vessels small.

A case of blindness, following the ingestion of a large dose of quinin, in a patient aged 40 years, is reported by de Schweinitz (*Prac. Med. Series*, Eye, p. 11, 1908). The exact amount of the quinin taken is not known. The patient presented the usual symptoms and signs of quinin blindness: blindness of sudden development and absolute in character during its existence; gradual restoration of central vision; slow renewal of central color-sense, with ultimate return; permanent reduction of light-sense and contraction of the visual field; extreme pallor, also permanent, of the optic discs and marked contraction of the retinal vessels. The visual fields were elliptically contracted with the longest axis in the horizontal direction. In the writer's case the visual fields showed an exceptional condition in that there were areas of preserved visual field in the form of islands in which the perception of white was retained.

de Schweinitz confirmed Schwalbe's observation that caffein administered during a quinin amaurosis will further contract the visual field. One hundred and twenty grains of citrate of caffein were given the patient during eight days, with the result that the visual fields were reduced five degrees in all meridians.

A typical example of quinin amblyopia is described by D. N. Manolescu (*Klin. Monatsbl. f. Augenheilk.*, Sept., 1911). A woman, aged 30, took about 13 grams of sulphate of quinin, most likely to produce miscarriage. After fifteen minutes she had violent headache, vertigo and tinnitus, and she vomited and lost consciousness. A physician, hurriedly called, made injections of caffein. After two hours she regained consciousness, but her sight and hearing were entirely lost. On the second day hearing was partially restored. At the examination on the third day vision was nil, the perception of light was very much diminished, both pupils were fully dilated and immovable, the fundus was anemic and yellowish-red, the retina was slightly opaque, the discs were pale and yellowish-red, the borders hazy, especially at the temporal region, the veins enlarged, and the arteries, as thin as threads, could be traced only as far as twice the diameter of the disc. The treatment consisted of milk diet, laxatives and injections of strychnin into the temple. Central vision returned in 8 days; V = I in left eye in 2 weeks.

This course of the disease was in conformity with the majority of cases; the visual field for white gradually expanded within a year from a considerable concentric contraction to its normal dimensions, but remained narrower for colors; the peculiar fact was that the area for blue remained smaller than that for red. In most other observations the restoration of the visual field occurred within a year, sometimes later. In almost all cases total achromatopsia existed for a few days. In the author's case color perception was restored after 12 days.

The objective symptoms of quinin amblyopia may, according to the author, be divided into constant and inconstant. The constant symptoms in almost all cases are: maximal mydriasis in the first days of the intoxication, immobility of the pupils to light, anemia of the retina (which assumes an opaque, yellowish color) discoloration of the discs (which appear atrophic), and enormous narrowing of the vessels, especially of the arteries.

The pupils, in the case mentioned, commenced to react to light on the ninth day and were normal after a year. The veins, at first dilated, soon regained their normal width.

The prognosis of acute quinin intoxication is relatively good, as all disturbances disappear, excepting the contraction of the visual field for colors, the attenuation of the arteries and the relative discoloration of the discs.

Manolescu enumerates the different kinds of treatment and believes that none is of any avail. As a prophylactic measure, however, the medicinal use of quinin and other poisons with a specific action on the optic nerve (as alcohol, nicotine, etc.) must be borne in mind in such patients, as experience shows that their eyes are sensitive to doses smaller than those which were formerly without injurious effect.

Desiderio (*Year-Book,* p. 263, 1912) reported the history of a patient who had taken 300 grains of quinin with suicidal intent. On the evening of the same day there was no light perception. The discs were swollen, and the retinal vessels greatly narrowed. The retina was edematous with a cherry-red spot at the macula. In two weeks' time visual acuity was normal. The fields remained greatly contracted for over a month, but the field for white finally reached 30° up and 35° down and in, and 80° out. Tyson, in another case of quinin amblyopia, also notes the excellent central vision with fundi presenting apparently total atrophy of the optic nerve. Other points of interest in this instance were, the course of the disturbance—total loss of vision being followed by late secondary improvement of both central and peripheral vision, especially toward the nasal side; sclerosis of the retinal vessels, islands of vision appearing in parts of the field which later widened so as to absorb them; the color field improved but slightly.

Keiper's (*Ophthal. Record,* Oct., 1911) patient was a man 75 years of age. Following a spree he took 120 grains of quinin at night and was totally blind the next morning. One week later vision = 20/200. The fields were contracted 50 per cent. The usual fundus picture was present with an area of retinitis below the disc in the left eye. Six months later vision was much improved. Keiper considers the age of the man specially noteworthy. Welton saw a man of 31, who took 55 grains of quinin and one quart of whiskey for ''grippe.'' He awoke with hazy vision, and three weeks later showed atrophic pallor of the disks, greatly contracted vessels, and narrowed fields of vision.

A. T. Kulebiakin (*Westn. Oft.,* Oct. 19, 1911; review by R. Kaz) reports three cases of quinin poisoning, in one of which 6.5 grm., in another 10 grm. and in a third a tablespoonful of quinin was taken. In two of these cases the dose was employed for the purpose of producing abortion and in the third it was mistaken for soda. In about half an hour the symptoms of general poisoning appeared and complete blindness developed in approximately twelve hours, lasting in the first case ten hours and in the others two days. In all the cases normal central vision was restored, in the first case almost immediately, in the second in one month and in the third after some months. As regards the visual fields, in the first case they were normal when first examined but later on became somewhat contracted, in the second they were much contracted at first but within a month became normal, while in the third case the fields were ultimately contracted down to 5 degrees externally and to 10-15 degrees in other directions. The fundus presented the characteristic picture of quinin atrophy, contraction of the blood-vessels with pallor of the optic discs.

The chief interest of these cases consists in the restoration of normal central vision irrespective of the state of contraction of the peripheral fields. A similar case was related by Kubli at the Petersburg Ophthalmological Society (*Wiestn. Oft.,* p. 159, 1910), and another one was recently observed by the reviewer. In the latter case where two teaspoonfuls of hydrochloride of quinin were taken by a young woman, the eyes were first examined at the end of the first day after the poisoning. Consciousness had returned some hours previously, but the patient was unable to hear or see. There was no perception of light and the pupils were dilated and immobile. The fundus showed no change. Two days later the deafness had passed off and some vision was restored, although the patient was only able to walk like a blind person. The pupil still remained dilated. The fundus now showed the typical picture of retinal ischemia, pale discs, narrowed vessels and milky opacity of the posterior part of the retina, with a cherry-red spot at the macula. Central vision was normal but the field was contracted down to the fixation point.

Lawford (*Oph. Review,* p. 108, Apr., 1914) reviews an account of a case of quinin amaurosis by Terrien and Aubineau (*Archives d'Ophtal.,* Nov., 1913) as follows. A woman, aged 46, took at one dose 7.50 grm. of sulphate of quinin, in cachets. Three hours afterwards she complained of severe general malaise, and had hallucinations. When seen by a doctor about seven hours after the ingestion of the quinin, she had a rapid, compressible pulse, cold extremities, gastric pain, vertigo, and deafness. Two days later coma supervened and lasted twelve hours; at its termination the patient was completely deaf and blind; the pupils were widely dilated, the corneæ insensitive. On the following day hearing returned, but blindness persisted, with wide, immobile pupils.

On January 20, 1913, the patient was seen by Aubineau, but there is no statement as to the interval which had elapsed since the quinin was taken. At this date the pupils were equal, widely dilated, and immobile. There was no p.l.; patient could not recognize the position of a window, although she said that she occasionally perceived the shadows of moving people. Ophthalmoscopic appearances similar in the two eyes. Retina hazy, and of a yellowish tint. No special changes at the macula. Margins of the disc obliterated; at this point the blood-vessels best showing slight elevation of the papilla; vessels threadlike, and veins and arteries could not be differentiated.

Since the beginning of February vision had begun to improve, although slightly. The patient said that sunlight appeared to her pale and more like moonlight; she also stated that though she had some sight she was unable to guide herself even in her room. At this date pupils were equal, 5-6 mm. in diameter reacting to light, and in the left eye to accommodation. V. R. = 1/40; L. = 1/3, and No. 2 of de Wecker's types. Visual fields: R. contracted to the 10° circle all around; L. 30° outwards; 20° inwards; 10° above and below. Color vision very defective in the right eye; in the left, colors well recognized, and no central scotoma present.

Ophthalmoscopically, the R. papilla sharply defined, and not atrophic in appearance; surrounded by a narrow, grey band. Retinal vessels diminished. The artery passing below the macula appears as a white line from the disc outwards. At the macula is a whitish, roughly circular patch about the same diameter as the disc. This patch shows in its central part numerous punctate hemorrhages. L. papilla presents the same appearance and surroundings; the artery, which passes upwards and outwards, appears as a white cord from the disc as far as the macula, but beyond that it shows a narrow bloodstream. At the macula is a dark, oval patch.

March 11, 1913. Pupils widely dilated, R. more than L. Light reflex abolished on the right side, but present on the left. Both pupils react to accommodation. V. R. = 1/20 barely; L. = 1/2. Visual field greatly contracted on both sides for white; color fields could not be mapped. Ophthalmoscopically the papillæ are white with appearances of postneuritic atrophy. Arteries filiform, much narrower than the veins, although the latter are constricted. In the right eye they are bordered in places by white lines of periarteritis. In the left the appearances are almost identical, but the arteries are alone much narrowed, and are less sclerosed. Visual acuity improved steadily in the L. until on March 31st it was equal to 0.8. In the right eye it diminished until the patient could barely distinguish figures at a few centimetres. The visual fields for white on March 20th were much contracted, the R. not exceeding the 10° limit, while the L. was bounded by 10° on the nasal side, 20° above and below, and 30° outwards. The fields for colors could not be mapped. Even in bright daylight yellow, green, blue and red all appeared to the patient uniformly grey during the first few seconds. After six or eight seconds red became slightly recognizable, but the other colors could not be distinguished, and a diminution of the light at once caused the red to disappear. There was no central scotoma. Patient was not seen by the authors after May 31st, but a report from her sister gave the information that from the month of June the patient became almost completely blind; she could only see shadows; but was unable to distinguish individuals, or to tell a man from a woman.

W. E. Shahan (*Am. Jour. of Ophthalm.*, May, 1916) gives an account of a woman, aged 28 years, who had been given 1 oz. of quinin and an equal amount of ergot, in divided doses, during six hours of labor. On the following day the patient was found to be blind and deaf. Seventeen days afterwards the patient's pupils were elliptical in outline, but responded promptly to light. V. = perception of light over the centre of the field; retinal vessels very small, especially the arteries, which appeared as fine, silvery threads over the surface of the optic disc. The patient was treated by inhalations of amyl nitrite. Six weeks later her sight was R. E. 20/15; L. E. 20/60. Discs pale; retinal vessels small; total blue-green blindness. The condition noted some nine months after she was first seen, was R. V. 20/15. L. V. 20/38. The patient was unable to read ordinary print; fields much contracted.

Georges Porte (*Révue Méd. de la Suisse Rom.*, Mar. 20, 1916; review by Sydney Stephenson in *Ophthalmoscope*, p. 422, Aug., 1916) reports an unusual [small dose of the poison, followed by complete recovery] case of quinin amaurosis in an anemic woman, aged 23 years, who took one gramme of quinin upon October 7th, and upon October 9th two more grammes of the remedy. On the last-named date, after the second dose of medicament, she experienced headache and complained of buzzing in the ears. Shortly after the third dose, the patient became deaf. Her hands trembled a little. When she went to bed at 11:30 p. m. she could not see clearly, a symptom to which she attached but little importance at the moment. A medical man, who was summoned shortly afterwards, found, however, that sight was completely lost.

When examined by Porte, on the morning of October 10th, the patient was pale, extremely depressed, and called upon death to relieve her from her misfortunes. The pupils were fully dilated and motionless. No perception of light. Marked pallor of the optic discs, retina, and choroid. The retinal vessels were much contracted and altogether invisible in the peripheral parts of the fundi. The fovea centralis stood out as a small, rounded, red spot, similar to that seen in embolism of the central artery of the retina. A soft, systolic murmur, thought to be hemic, was present and most marked at the apex of the heart.

Treatment included rest in bed in a darkened room, purgatives, and diaphoretics, together with milk diet and a decoction of herbs (*tisane*). Locally, half a centimetre of sodium chloride with a little dionin added was injected beneath the conjunctiva. On the same evening the patient could occasionally perceive the light of the lamp. Next day (October 11th) the pupils were dilated and immobile. The retina was of a more normal color, and the red spot at the fovea was less pronounced. Vision = 0.6, but the field of vision did not extend farther than ten degrees from the fixation point. Colors were recognized at the fixation spot. On trying to get up, the patient suffered from giddiness and groped like a blind person. Trinitrine was prescribed. On the following day (October 12th), the patient was able to read a post-card that she had received. On October 14th the pupils were noticed to react to light, and on the following day, the visual fields extended from 25 degrees to 30 degrees from the fixation point. A couple of days later (October 17th), the patient was able to guide herself during the day, but at night showed signs of hemeralopia. On October 25th, central and peripheral vision, both for white and for colors, were normal. When seen eighty days after this last note, nothing was found amiss with the eyes, excepting a slight contraction of the retinal arteries. The cardiac murmur had disappeared.

Major A. Kirkpatrick (*Ophthalmoscope,* p. 420, Aug., 1916) gives an account of quinin poisoning with accompanying amblyopia. The patient, a woman aged 30, took, eleven months previously, about half an ounce of quinin sulphate in mistake for Epsom salts. She is said to have lost consciousness shortly after, and to have remained in that condition for three hours. She did not fully come round till fifteen hours had elapsed, and was then found to be completely blind and almost completely deaf. Her hearing was recovered after three days, and her sight gradually improved until at the end of three months she was able to read small type but was still blind at night.

Seven months after the quinin was taken, her sight began to fail again, and in September, 1913 (four months after the secondary failure had commenced) the vision in each eye was reduced to light perception.

On examination, the right pupil was semi-dilated and reacted very sluggishly, and the left pupil was dilated and inactive. Both nerve heads were very white, the left being especially so. Atrophic cupping was not apparent. The superior nasal artery of the left eye was much thickened and almost obliterated, whilst overlying it, as it crossed the nerve edge, was seen a mass of hyaline, shaped like a cumulus cloud, and about one-twelfth the disc in size. Similar changes were seen in the right eye, but here it was the inferior nasal artery that was affected and the hyaline was not quite so large. Beyond the retinal vessels appearing somewhat unduly small, no other abnormality was observed.

She was advised intramuscular injections of strychnine with cyanide of mercury, inhalations of amyl nitrite, and to induce hyperemia by means of a Bier's suction glass.

The treatment was carried out for about three months without any great benefit, but vision had since considerably improved and the patient was able to walk about freely by herself and able even to read large type.

Louis Levy (*Jour. Texas State Med. Ass'n.,* Nov., 1916) reports the case of an adult man who took almost a half ounce of quinine in mistake for Epsom salts. He first noticed blindness about three o'clock the next morning. For three days he could see absolutely nothing, not even light. After this, vision gradually returned until he was seeing very well, although everything looked smoky. Later, vision again failed until he had perception of light. Upon examination Levy found dilated pupils, which did not react to light. The ophthalmic findings at the same time were as follows: Both discs very pale, vessels small, with colloid excrescences found in elderly people. The man was given the following treatment: strychnine, 1-30 gr. t. i. d., amyl nitrite inhalations and general elimination. Later, the blood-vessels seemed larger and the discs not so pale. Vision, however, still remained the same.

John E. Weeks (*Trans. Am. Oph. Soc.,* p. 593, 1916; review in the *Ophthalmoscope,* p. 179, Mar., 1916) reports the occurrence of amblyopia in a lady, aged 51 years, who received about 315 grains of quinin hydrochloride *per rectum,* and although some of the liquid escaped during the injection, it was thought that about one-half of the quinin was retained. Fourteen and a half hours afterwards, the patient was found to be blind, with dilated pupils. There were complaints of tinnitus and deafness. When examined by Weeks twenty hours after the injection of the quinin, the vision and pupils were as noted. The optic discs were very pale and the retinal vessels possessed about two-thirds their normal dimensions. The retina was edematous and pale throughout, except at the macula. The treatment included repeated high, copious, saline enemata; glonoin, 1/100 grain every three hours; strychnine, 1/40 grain, three times a day.

On the following day, the patient could distinguish a bright light, 24 hours later, she could see hand-movements; and on the third day, could count fingers at 4 inches. Seven days after the sight had failed, it was found that the field of the right eye fell everywhere within the 10° circle, except on the temporal side where it extended to about 24°, whereas that of the left eye was confined to the 15°

circle. Ten days after the failure of sight, V. 20/30 —., and on the following day the lumen of the retinal arteries was found to have become irregular and the vessel walls thickened. Improvement in these respects followed the administration of caffein, 2 grains, in addition to the glonoin and strychnine. Forty days after the onset of the amblyopia, the light perception, as tested by Snellen's photometric letters, was 75 per cent. About a month later, Parinaud's photometric bars indicated a light perception of 80 per cent. V. = 20/20—. The optic discs presented about two-thirds normal capillarity. The retinal arteries had about one-half their natural size, while the veins were but slightly narrowed. The fields for white were still concentrically contracted, but approaching their normal limits. Field for red very small. Reduction in the light sense was believed by Weeks to account for the patient's constant complaint that she could not see the light, even although vision had become practically normal.

A second case is of a girl of 16 years who was treated for pneumonia by the administration in all of 2 grammes of optoquin, spread over 36 hours. Four hours after the last dose, the girl complained that she could not see. Six days later, she began to distinguish light, and in six weeks' time, V. = 20/30. Forty-four days after the onset of the mischief, she was first examined by Weeks. V. = 20/30. Optic discs paler than normal, but not markedly so. Retinal arteries reduced to about one-half their usual size. Walls of the retinal blood vessels thickened. Fields: R. E. above, 20°; below, 15°; nasally, 20°; temporally, 35°. L. E. above, 25°; below, 25°; nasally, 20°; temporally, 35°. The white fields, estimated about two months after the optoquin had been taken, showed loss of most of the lower halves, more pronounced twelve weeks later, when V. = 20/30 —. Color vision "very indefinite." Light perception about 80 per cent.

Weeks also furnishes a supplementary report of a case published in 1881 by the late H. Knapp (*Archives of Ophthalmology,* Vol. X, 1881, p. 220). Briefly, loss of vision followed the administration of quinin by the rectum and the mouth. The patient was seen by Knapp almost a year after these occurrences. V. was 20/20, and color perception was normal. But the optic discs were white, the retinal arteries very small, and there was a moderate concentric contraction of the visual field in each eye. Two years later, quinin was again given, and again the child developed amblyopia and became green-blind. The fields were much contracted. She lost her green-blindness, and recovered V. of 20/30. The optic discs, however, remained white, the retinal vessels small, and the fields contracted.

The condition, when the patient was examined by Weeks, some thirty-eight years after, was as follows.—R. V. 20/30, L. V. 20/40. Vertical nystagmus. The optic discs were almost chalky-white, and the blood-vessels few in number and reduced in size. The fields of vision showed concentric contraction for white and for colors.

A remarkable case of *quinin amblyopia from rectal administration* is reported by C. S. G. Nagel (*Am. Jour. of Ophth.,* p. 54, 1919). The history is as follows: On July 18, 1918, Mrs. G. H., æt. 60, after an operation received an enema of unknown character for heart failure, after which she became unconscious for about thirty hours; and thereafter found herself totally blind for a month. She then began gradually to improve for several months, but had apparently made no further progress during the last few months. Both the patient and her husband stated that according to current rumor a mistake in regard to the enema had been made.

Examination showed R. Hm. + 0.75 = 0.8; L. Hm. + 0.25 = 0.6 with + 3, Snellen 1 with some difficulty. Visual fields contracted concentrically, close to point of fixation, except that in the left upper quadrant of each field there was a normal roundish area for white, and all colors to a maximum extent of 25° right. The fundus in both showed retinal arteries as well as veins very narrow, with absolutely white sheathing, more particularly of the arteries (thickening of walls). Both discs were of extreme pallor and sharply-defined. Macula normal. The diagnosis of quinin amblyopia was made, with just a possible alternative of embolism of both central arteries (of which—simultaneously bilateral—there are four cases now on record), or rather remotely, ischemia retinæ from loss of blood. After five weeks of strychnin treatment, vision had improved to 0.9 and kept the same under same treatment up to the beginning of November. Visual fields had remained about stationary.

For the prevention of "post operative gas pains" the surgeon had ordered 5 grains of quinin hydrochlorid per enema, every four hours. After 30 grains (some always being lost, he figures on an actual intake of 25 grains) patient showed signs of failing heart. This was not attributed especially to the drug. However, the order was changed to every twelve hours. Instead the nurse administered the clysma every two hours. After 60 grains in all, the general condition of the patient becoming alarming (weak pulse, etc.) the drug was stopped. Loss of consciousness and blindness following, as related by the patient. No eye examination was made at any time during seven months.

The most recent, complete and practical monograph on the subject of cinchonism with amblyopia and amaurosis is comprised in the series of papers by R. H. Elliott (*Am. Journal of Ophthalm.*, beginning with the August No., 1918). See, also, **Toxic amblyopia.**

Quindecagon. A plane figure of fifteen sides and angles.

Quincke's disease. ANGIONEUROTIC EDEMA. Giant urticaria; edematous form of urticaria. See, also, **Orbit, Edema of the**, p. 9115, Vol. XII of this *Encyclopedia.*

Mazza (*Prac. Med. Series,* Eye, p. 45, 1907) reports three of these curious cases. The first case was a woman, 45 years old, who experienced, one night, a swelling of the left eye with no pain. She was unable to open the eye. She attributed the trouble to sleeping in a draught. There was a true edema of the lids and conjunctiva. The skin of the lids was distended without any alteration of color or a solution of continuity. The conjunctiva showed no wound, foreign body, pain or irritative phenomena. Vision was normal. The patient suffered from irregular menstruation and had from time to time an inflammation of the hands and knees, which left a pruritus. The edema promptly disappeared with the use of astringent applications and purges.

The second patient, at the age of 15 years, following exposure to cold, was taken at night, with swelling of the O. D. and at the same time loss of voice without pain. The edema involved the lids and conjunctiva of the inferior cul-de-sac. There was no alteration in color, no sign of irritation and no pain. Purges and astringent applications were prescribed and the next day the edema had disappeared. One month later the attack was repeated. At this time a throat specialist found edema of the vocal cords, which disappeared in twenty-four hours. For some time the attacks recurred at intervals of four or five days.

The third case was a woman, anemic and constipated. For five or six years she had been subject to transient edema of the face, which appeared with her menstrual periods and lasted usually twelve to twenty-four hours. Both lids were edematous. Mazza believes all these cases should come under the head of Quincke's disease.

Quinol. See **Hydroquinone.**

Quinosol. CHINOSOL. POTASSIUM OXYQUINOLINESULPHONATE. This agent appears as yellow crystals with an astringent, aromatic taste readily soluble in water. In 1:1000 solution H. V. Würdemann finds it of value in the local treatment of mycotic keratitis.

Quinquangular. Having five angles.

Quintuple. (a) Fivefold. (b) To increase fivefold.

Quintus Serenus. The son of Serenus Sammonicus, and author of a versified collection of prescriptions, compiled from Pliny and Dioscorides. In this work some 37 verses are entitled "Oculorum Dolori Mitigando." Quintus Serenus died about 235 A. D.—(T. H. S.)

R

R. An abbreviation for *recipe* (take), *right, remotum* (far-point), and *Reaumur.*

Ra. The symbol of radium.

Rabbit's bile. Morax (*Annales d'Oculistique,* Nov., 1907; review in *Oph. Review,* p. 85, Mar., 1908) pointed out that Neufeld was probably the first to record the bacteriolytic action of a rabbit's bile. He states that if to 2 cc. of a culture of pneumococcus in bouillon kept at 37° C. for 24 hours, one adds a small amount of rabbit's bile, the culture clears rapidly, and at the end of a certain time the bouillon can be demonstrated to be free of any activity, tested microscopically, by culture or by inoculation. He adds that bile from the rabbit is decidedly more active in this way than bile from man, dog, rat or goat. This matter has been further investigated by others, especially Nicolle and Adil Bey, who have shown that it is in the biliary salts that the activity lies, and have arranged them in order of efficacy.

One of the most destructive diseases to which the eye is liable is ulcer of the cornea caused by the pneumococcus, and while this is in many cases amenable to treatment by the cautery and other means, in really bad and advanced cases one would be thankful for any further assistance in treatment. Gabrielides first treated cases of hypopyon ulcer successfully with the bile of both rabbit and sheep. Morax has made attempts in cases of pneumococcus infection to further investigate the value of the new application. He usually employed the bile just as it was, but taurocholate of soda in 2 per cent. solution makes another convenient application of similar nature. His first case was one of conjunctivitis of pneumococcal origin with abundance of organisms; these were greatly reduced in numbers in one day by the use of bile. In another case of pneumococcus infection, this time in the form of an ulcer of the cornea in a man of 54, along with other treatment two instillations of bile were employed, and the process of advance was checked, repair began almost at once, and healing proceeded rapidly and satisfactorily. One or two other similar cases are related in which the beneficial effect of the bile was quite evident, and then an example of hypopyon keratitis due to the bacillus pyocyaneus, in which bile had absolutely no effect, unless perhaps that of increasing the pain.

The fact that in the cases related Morax employed other customary therapeutic means detracts of course to some extent from the value of these observations, considered from the point of view of mere experimental tests of the action of bile, but Morax very justly points out that he does not regard bile as a panacea, but as a useful adjunct to other means, as an important therapeutic agent, not as supplanting all others, but assisting them. Thus, the organism causing hypopyon ulcer of the cornea, though it lies in the superficial layers, it is true, may yet be deep enough to escape to some extent the bacteriolytic action of the bile; therefore he employed light curettage before instillation. The atropine, too, has so decidedly an analgesic effect that he did not care to omit the use of it as well. Besides, the influence of the bile is but transitory, and the antiseptic action must be kept up. He considers, further, that if we can limit the sphere of action of the cautery, that most invaluable agent, we may have smaller and fainter opacities resulting. The application of bile caused a very considerable amount of smarting pain, which lasted from one to several hours.

Rabies. HYDROPHOBIA. A disease of the nervous system, which, as recent investigation goes to prove, is caused by an ultra-microscopic, filter-passing organism of the class chlamydozoa. This organism is apparently responsible for the "cell inclusion" Negri's bodies, which are a constant feature of the disease.

Santos Fernandez (*Archivos de Oftalmologia,* Sept., 1915), made a careful examination of the ocular fundus in two fatal cases of rabies, without finding any indication of change in the choroid, retina, or optic nerve. See, also, **Hydrophobia,** p. 6083, Vol. VIII of this *Encyclopedia.*

Race and the eye. RACIAL INFLUENCES ON THE EYE AND ITS DISEASES. In addition to the matter touching this subject under **Ethnology of the eye,** p. 4527, Vol. VI of this *Encyclopedia,* the following account by J. N. Roy (*Canadian Med. Assocn. Journ.,* p. 144, Feb., 1919) will be found of great value.

The author's paper gives the results of a recent tour throughout the Dark Continent, where he visited twenty-two different colonies and examined the anatomical, physiological, and pathological condition of about five thousand negroes of one hundred different tribes. He deals with their refraction, vision during the day and night, and accommodation, comparing the eyes of the blacks with those of other races.

As his subjects were illiterate he used for determining the acuity of vision rectangular types with one side missing, and found this test worked very well.

He used skiascopy for the refraction.

The African light is very bright, and the atmosphere very clear. Experiments led to the conclusion that vision in the same person is better in Africa than in Europe. An emmetropic eye which, in the northern countries, has with good light a vision of 5—5 or even 6—5, can see in Africa one metre farther away, i. e., a vision of 7—5. This unity of 7—5 is, therefore, in this paper considered as the normal vision of an European in Africa or in other tropical countries.

A glance at the geography and ethnology of the Dark Continent shows that the different races came in contact according to certain circumstances worth mentioning. The negroes of the Senegal Soudan intermarried with their neighbors of the north, the Berbers and the Arabs; and their offspring, the Moors, peopled chiefly Mauretania. Those of the northeast were gradually absorbed by the Egyptians who were always at war with the Ethiopians; and their union with the Fellahs gave origin to the race of the Peuhls and the Foulahs, who live in the neighborhood of the Senegal river, the upper part of the Niger, and in the Fouta Djalon in French Guinea. The Arabs of Yemen made repeated incursions into Africa, crossed the coast of Somalis, and reached Harrar the capital of the country of Gallas in Abyssinia, where they remained in possession for a long time.

The negroes who came in contact with these different races inherited from them many diseases, chiefly syphilis and trachoma. Smallpox also made terrible ravages, chiefly where the means of communication are naturally easier than in the wild forest. The same may be said of purulent ophthalmia. In a general way the eyes of the people living north of the fifth degree of latitude north are not as healthy as those living south, on account of the lesions due to purulent ophthalmia, variola, trachoma, and the constant irritation of the sand.

Strabismus, due usually to corneal scars, or amblyopia from other sources, is also more frequent in the northern part.

Roy made a complete tour around the African continent, penetrating at many points even to a great depth.

He concludes that the people of the south were first infected by those of the north, who in turn had been contaminated by the Indo-Europeans.

A continent in the past probably bound Asia and the south of Africa; of which the islands of the Soudan are the vestiges. The Hottentots and the Bushmen with their Mongolian blood are a living proof of this hypothesis. The last descendants of these tribes, almost extinct nowadays, live grouped together chiefly on the frontier of Rhodesia, German South-West Africa, and the Portugese Angola.

Upon close examination of the eyes of the negroes, one is astonished at the considerable amount of pigment contained therein. At times it is even found on the ocular conjunctiva opposite the external canthus. The iris and the choroid are saturated with it, and even in certain cases there is a physiological condition of melanosis of the soft palate and of the gums.

Refraction shows that their eyes are almost all emmetropic, provided there is no alteration of the cornea due to previous diseases. Statistics have given the following results: Simple myopia is found in the proportion of about 1.5 per 100, and then it is always of a mild degree. Roy never had to use a glass higher than four diopters, and this was with albinos. In passing, it is worthy of note that this pigmentary anomaly is far more frequent in Africa than elsewhere.

Myopic astigmatism is found in about the same proportion as simple myopia, i. e., 1.5 per 100; and the author never had to use a cylinder higher than —2.5 to correct the error.

There is an absence of keratoconus and keratoglobus in Africa.

Simple hypermetropia and hyperopic astigmatism are found in about 2.5 per 100. The highest degree of hypermetropia was corrected by a sphere of + 3.5, and astigmatism by a + 2.5 cylinder. The writer saw but few cases of compound astigmatism, and those chiefly among albinos. He never had a case of mixed or irregular astigmatism.

All these percentages are based on cases with absolutely transparent corneas. It goes without saying that alterations of the cornea due to diseases are met with in Africa as elsewhere. These percentages are based on an average of the whole continent. Where schools of instruction have long been established, they may be too low; but at places where almost every one was emmetropic, they are certainly too high. Practically all cases of ametropia were corrected by very weak glasses.

In a general way, the negroes had excellent eyesight. In rare cases, he even observed that a correction of two to three diopters of either hypermetropia or myopia could improve their vision up to 9—5 and even 11—5. The highest normal vision recorded was one of 20—5, and this was in a man affected with sleeping sickness. Trypanosomiasis affected the native eye but little. The average vision of the natives of Africa is 12—5. More than any other race have they the faculty of seeing to a great depth in water. In spite of the most careful researches, even in eyes suffering from disease, Roy never observed any alteration of the color vision or hemianopsia.

Negroes have a great power of vision in the dark. Roy made a series of experiments to compare their sight at night with the nocturnal vision of Europeans. The subjects were first refracted. There was a larger amount of pigment in the retinæ of the negroes than in those of the whites; but the rods in both races have the same form. We are forced to believe therefore that their excellent vision in the dark is due to the greater use of their eyes at night compared with ours. The writer noticed the same thing with the Indo-Chinese, the Malays, and redskins, whose vision at night is very good; and even among the Hindoos, whose origin is Aryan.

Roy paid particular attention to the power of accommodation. It was easy to gather positive facts on account of the presence, at different places, of scholars who could read fairly well. Researches on the subject show that the natives of the Dark Continent have a better power of accommodation than whites. A study of a series of fifty observations shows without doubt the existence of this superiority, and, besides, corroborates all previous statements. These observations are practically alike, and were all made on emmetropic cases. To get the *punctum proximum* the writer used the smallest characters of the de Wecker chart.

Observation	Sex	Tribe	Age	Amplitude of accommodation	Emmetropic vision
1	man	Ouolofs	16 years	0.07 cent. = 14.28	14–5
2	man	Ouolofs	18 years	0.082 cent. = 12.19	12–5
3	man	Bambara	17 years	0.08 cent. = 12.5	13–5
4	man	Mandigue	29 years	0.107 cent. = 9.34	12–5
5	man	Mandigue	15 years	0.068 cent. = 14.7	10–5
6	man	Bambara	20 years	0.085 cent. = 11.76	15–5
7	man	Malinke	22 years	0.088 cent. = 11.36	12–5
8	man	Soussous	24 years	0.09 cent. = 11.11	12–5
9	man	Soussous	30 years	0.103 cent. = 9.7	11–5
10	man	Soussous	23 years	0.09 cent. = 11.11	12–5
11	woman	Fantis	14 years	0.067 cent. = 14.92	16–5
12	woman	Apollonienne	14 years	0.07 cent. = 14.28	12–5
13	woman	Fantis	13 years	0.065 cent. = 15.38	15–5
14	woman	Acera	15 years	0.072 cent. = 13.88	11–5
15	woman	Aehantis	22 years	0.084 cent. = 11.9	9–5
16	woman	Aehantis	18 years	0.077 cent. = 12.98	14–5
17	woman	Yorouba	29 years	0.106 cent. = 9.43	11–5
18	woman	Ibos	20 years	0.088 cent. = 11.36	14–5
19	woman	Egbas	22 years	0.08 cent. = 12.5	15–5
20	woman	Yorouba	25 years	0.102 cent. = 9.8	10–5
21	man	Minas	23 years	0.085 cent. = 11.76	14–5
22	man	Minas	23 years	0.08 cent. = 12.5	17–5
23	man	Evhe	25 years	0.087 cent. = 11.49	18–5
24	man	Dagomba	19 years	0.07 cent. = 14.28	11–5
25	man	Fons	19 years	0,075 cent. = 13.33	10–5

Observation	Sex	Tribe	Age	Amplitude of accommodation	Emmetropic vision
26	man	Bassa	23 years	0.073 cent. = 13.69	14–5
27	man	Malumba	21 years	0.07 cent. = 14.28	15–5
28	man	Kumba	24 years	0.082 cent. = 12.19	13–5
29	man	Malumba	21 years	0.074 cent. = 13.51	10–5
30	man	Bassa	18 years	0.07 cent. = 14.28	12–5
31	man	Loango	16 years	0.07 cent. = 14.28	10–5
32	man	Yacoma	13 years	0.067 cent. = 14.92	13–5
33	man	Batetela	16 years	0.065 cent. = 15.38	10–5
34	man	Azande	15 years	0.075 cent. = 13.33	12–5
35	man	Bangala	16 years	0.075 cent. = 13.33	11–5
36	man	Yacoma	15 years	0.07 cent. = 14.28	15–5
37	man	Basonge	14 years	0.065 cent. = 15.38	11–5
38	man	Bangala	14 years	0.068 cent. = 14.7	12–5
39	man	Bakumu	15 years	0.075 cent. = 13.33	10–5
40	man	Basoko	14 years	0.062 cent. = 16.12	12–5
41	woman	Baluba	14 years	0.068 cent. = 14.7	12–5
42	woman	Mongo	18 years	0.074 cent. = 13.51	11–5
43	woman	Yacoma	17 years	0.07 cent. = 14.28	15–5
44	woman	Basoko	15 years	0.066 cent. = 15.15	17–5
45	woman	Basoko	20 years	0.08 cent. = 12.5	10–5
46	woman	Bangala	14 years	0.06 cent. = 16.16	13–5
47	woman	Bapoto	16 years	0.065 cent. = 15.38	12–5
48	woman	Mongo	16 years	0.068 cent. = 14.7	14–5
49	woman	Basoko	19 years	0.07 cent. = 14.28	11–5
50	woman	Loango	15 years	0.063 cent. = 15.87	10–5

If we compare these figures with those of Donders' chart, we see to what point the amplitude of accommodation in the negro is superior to that of the white, although the difference is not so marked as it looks.

The writer regrets that he had to limit his researches to the period of life between thirteen and thirty years. Younger than that, his subjects could not read sufficiently to give definite answers. Moreover, negroes cannot give exact answers about their birthday. At times they mention a certain number of years before or after a definite event in the history of their country, and from this event, as well as we know it, we have to deduce their age. Roy regrets this as it would have been interesting to know when presbyopia develops among them. However, our limited statistics, with subjects whose age was well known, show that it develops a little later than with whites. This is but logical on account of their excellent power of accommodation, and the rarity of latent hypermetropia. This fact is worth mentioning because, according to some authors, among whom are H. Campbell Highet, of Singapore, and J. Santos Fernandez, of Cuba, who have made experiments in their own country, presbyopia seems to appear from five to six years earlier in the tropics than elsewhere, and this not only among the Europeans who have been residents for a certain time, but also among the natives. According to them, the high temperature, causing a general depression of the organism, and indirectly a diminution of the power of accommodation, would explain this phenomenon; besides the mode of life and the feeding of these different people could also have something to do with this condition. It is not so with negroes. Moreover, the population of Singapore is composed of many nations in which the yellow element represented by the Chinese, the Japanese, and the Malays predominates. In Cuba there are Spaniards, Creoles, Chinese, Americans; and the other residents have lost, either as a result of their prolonged stay, or through intermarriage, a part of the characteristics of their own race. These anemic white or yellow peoples, often affected by malaria, or born from diseased parents, are from every point of view far less resistant than the blacks, whose organism by heredity is used to life in the tropics.

The writer points out that if we examine, in a general way, the visual acuity of the different races of the globe, we see that it varies greatly in individuals of the same origin. The different peoples of the earth, from an ethnological standpoint, may be divided into three large families: the white, the black, and the yellow. Indeed, if we consider carefully the characteristics of the Malays and the redskins, we find that the representatives of those two races have had Mongolians for ancestors. The color of the skin, the shape of the eyelids, the development of the malar bones, the flattening of the base of the nose, the thickness of the hair, and, generally speaking, their facial expression, are all arguments in favor of this theory. Moreover, we find in the language of certain Indian tribes of South America, a number of expressions very similar to some Japanese words; and in Mexico, ruins of temples have been found with symbols which are undoubtedly vestiges of those which adorned the shrine of Buddha.

As with the white races myopia, quite frequent in Japan and China, is met with almost exclusively among the educated class; and, in spite of what certain authors say, it is not a national defect. Hypermetropia is met with a little more frequently.

The Malays, Philippinos, Hovas, Esquimaux, Laplanders, and the redskins are, like the negroes, almost all emmetropic; and Steiner has the same opinion of the population of Java.

Roy's statistics on ametropia of mulattoes and other half-breeds show that vision in both has about the same characters. In detail, the percentage is as follows: 50 per cent. of hypermetropic astigmatism both simple and compound, 25 per cent. of myopic astigmatism simple and compound, 20 per cent. of hypermetropia, and 5 per cent. of myopia. C. P. Jones, in a paper on the refraction of the half-breeds, comes to the same conclusion. His figures show 78 per cent. of astigmatics, of which 51 per cent. is of the simple or compound hypermetropic type, and 27 per cent. of the simple or compound myopic form. There is 19 per cent. of hypermetropia and 3 per cent. of myopia. The word Indians in this paper means half-breeds only. It does not include the redskins, for nowadays these are seldom met with in their pure condition. To study them carefully, one has to go to Mexico or to Central or South America.

No irregular or mixed astigmatism was found among the mulattoes or other half-breeds, and all the corrections were of a slight degree.

Roy recalls the opinion that the depth of the orbit may have some influence on the development of the eye in its antero-posterior diameter and, consequently, upon the refraction. To deep orbits correspond myopia; to shallow ones, hypermetropia. Moreover the orbital diameter is in relation to the shape of the head, and the more dolichocephalic the cranium, the deeper is the orbit; and vice-versa. We know that, in a general way, yellow peoples are more or less brachycephalic, whites mesoticephalic, and negroes almost all dolichocephalic. The writer denies this statement. Outside of anomalies of refraction, due to abnormal curvature of the lens, or to previously existing diseases, there is no rule to explain the causes of ametropia other than direct heredity. These hereditarily weak eyes succumb to the effect of fatigue brought on by delicate work, corneal lesions, defective light, and the constant use of poor printing. Moreover, according to Broca's measurements of the orbit, the Dutch with their shallow cavities are frequently myopic, while the Esquimaux with their large orbits are almost all emmetropes.

The vision of the different peoples is also proportionate to their intellectual development. Taking the white race as a point of comparison, we see that the eyesight of the Chinese and of the Japanese is similar to ours; and of all the different branches of the yellow race it is the worst. The Esquimaux and the Laplanders, living in northern countries, are next in the scale, with a vision superior to that of their ancestors. The Philippinos, Hovas, Malays, and the redskins have still better sight.

Warm climate seems to have a certain influence on the development of the ocular pigment. In individuals of the same race, born in different places, more pigment is met with in the tropics than in cold countries. As a result of this there is a larger absorption of light rays, and an improvement of the sight, although the intensity of the light plays a great part. See **Ethnology,** p. 4535, Vol. VI of this *Encyclopedia.*

Studying the moral and the physical condition of the mulattoes and other half-breeds, we find that they have inherited from the whites all their defects and even their pathological atavism. When good qualities exist—which is exceptional—they are always poorly developed. Their eyes are not as good as those of the redskins and the negroes, but may be compared to ours.

The power of accommodation of the yellow race is (as in the white) superior to the figures of Donders. The writer's statistics show it to be about equal in both races. The same may be said of mulattoes and half-breeds.

Of all human beings, the blacks without doubt represent the lowest step of civilization. Their eyes and ears are developed to the highest possible degree of physiological function. Next in the scale are the yellow peoples of the islands of Oceania, then those of Indo-China, the redskins of Mexico, Central and South America, the Laplanders, the Esquimaux, and lastly, the Chinese and the Japanese. The whites are the highest in the scale with the poorest vision.

The ocular pigment seems to have a definite influence on the perception of objects, and in negroes it is one of the main causes of their excellent vision. It absorbs some rays of light and neutralizes those that are irregularly reflected on the retina.

With the civilization brought to them by the Europeans, who now control almost the whole of Africa; with their mode of living changed chiefly in the increased absorption of more or less adulterated food and of alcoholic beverages—which nowadays they even make themselves—with the advance of instruction in schools and workshops; with (at places) the use of artificial light, it is a question how long the natives will retain their visual power, at present so perfect.

Rachistovainization, Ocular symptoms from. Balbuena Fernandez (*Archivos de Oftalmologia,* August, 1915) records the case of a woman of forty years who was operated upon for extirpation of the right tube and ovary, using as anesthetic stovain in intrarachidic injection. Two weeks later she noticed that she saw double and that the left eye squinted. A month later she came for examination. There were all the symptoms of paralysis of the sixth pair. Iodide of potash appeared to favor recovery, which was complete in two months. Twenty other cases have been discovered by the author in which no other cause of paralysis could be found but the intrarachidic injection of stovain. See, also, **Stovain.**

Racine. (F.) Root.

Racine supérieure de la couche optique. A term applied by Meynert to a tract of nerve-fibers in the anterior pillars of the fornix.

Radde's color charts. These show 21 shades arranged in 42 rows. Each horizontal row is marked with a number; each vertical one by a letter. Hence each shade is indicated by two indices.

Radex. One of the numerous forms of tinted glass now on the market, intended to protect the eyes from glare or from injurious rays of light. Spectograms comparing this with other forms of protective glass will be found in the *Trans. Oph. Sec. A. M. A.*, p. 256, 1915.

Radian. The angle (57° 17′ 44″) subtended at the center of a circle by an arc equal in length to the radius. See **Centrad**, p. 1955, Vol. III of this *Encyclopedia*.

Radiant. Shooting or emitting rays of light; giving out rays; resembling rays.

Radiant energy. Energy transmitted through, or by means of, the luminiferous ether.

The effects of this force on the eye is voluminously discussed (as the result of much experimentation) in the monograph of F. H. Verhoeff and Louis Bell (*Proc. Am. Acad. Arts and Sciences,* 51, No. 13, p. 629, July, 1916), with a systematic review of the literature by C. B. Walker. As a result of these investigations the authors come to the following conclusions:

1. The liminal exposure capable of producing photophthalmia to the extent of conjunctivitis accompanied by stippling of the cornea, is in terms of energy about 2×10^6 erg seconds per square cm. of abiotic radiation of the character derived, for example, from the quartz lamp or the magnetic arc. About two and a half times this exposure, i. e., 5×10^6 erg seconds per square cm. is required to produce loss of corneal epithelium.

2. The abiotic action of the cornea and conjunctiva produced by any radiating sources follows the law of inverse squares and is directly proportional to the total abiotic energy received. It can therefore be definitely predicted from the physical properties of the source.

3. After exposure of the eye to abiotic radiations there is a latent period before any effects clinical or histological become perceptible. This period of latency in a general way varies inversely with the severity of the exposure, but a theoretical latency of 24 hours or more corresponds to an exposure entirely subliminal.

4. The combined effect of repeated exposures to abiotic radiations is equivalent to that of a continuous exposure of the same total length, provided the intermissions are not long enough to establish reparative effects. Approximately the exposures are additive for intermissions of somewhat less than 24 hours. Exposures of ⅓ the

liminal given daily begin to show perceptible effect after about 6 exposures. Daily exposures of 1/6 the liminal repeated over long periods produce no effect whatever, except to give the external eye a degree of immunity against severer exposures. Actual abiotic damage to the external eye renders it temporarily more sensitive to abiotic action.

5. Abiotic action for living tissues is confined to wave lengths shorter than 305 $\mu\mu$, at which length abiotic effects are evanescent, while for shorter wave lengths they increase with considerable rapidity.

6. For the quartz arc and the magnetic arc the abiotic activity of the rays absorbed by the cornea is eighteen times greater than those which are transmitted by it. To affect any media back of the cornea requires therefore at least eighteen times the liminal exposure heretofore mentioned.

7. Even with exposures as great as one hundred and fifty times the liminal for photophthalmia the lens substance is affected to a depth of less than 20 μ, and this superficial effect undergoes in the rabbit complete repair. Such enormously intensive exposures, which we obtain with the magnetite arc and double quartz lens system may completely destroy the corneal epithelium, corpuscles, and endothelium. The corneal stroma may be strongly affected by waves shorter than 295 $\mu\mu$. which it completely absorbs, but is very slightly affected by the remaining abiotic radiation.

8. The histological changes produced by abiotic radiation are radically different from those produced by heat, and the cell changes are best seen in flat preparations of the lens capsule. The most characteristic change is the breaking up of the cytoplasm into eosinophilic and basophilic granules.

9. Changes in the lens epithelium like those following abiotic action, including the formation of a "wall" beneath the pupillary margin, are not exclusively characteristic of abiotic action, but may be produced by ordinary chemical reagents. They are, therefore, characteristic not of abiotic action alone, but of chemical action in general.

10. Abiotic radiations certainly do not directly stimulate, but on the contrary apparently depress mitosis. Their action in this respect also is materially different from that of heat.

11. The lens protects completely the retina of the normal eye even from the small proportion of feebly abiotic rays which can penetrate the cornea and vitreous humor.

12. Experiments on rabbits, monkeys and the human subject prove

that the retina may be flooded for an hour or more with light of extreme intensity (not less than 50,000 lux), without any sign of permanent injury. The resulting scotoma disappears within a few hours. Only when the concentration of light involves enough heat energy to produce definite thermic lesions is the retina likely to be injured.

13. The retina of the aphakic eye, owing to the specific and general absorption of abiotic radiations by the cornea and the vitreous body, is adequately protected from injury from any exposures possible under the ordinary conditions of life, even without the added protection of the glasses necessary for aphakic patients.

14. To injure the cornea, iris, or lens, by the thermic effects of radiation, requires a concentration of energy obtainable only under extreme experimental conditions.

15. Infra-red rays have no specific action on the tissues analogous to that of abiotic rays. Any effect due to them is simply a matter of thermic action, and such rays are in the main absorbed by the media of the eye before reaching the retina.

16. Actual experiments made on the human eye show conclusively that no concentration of radiation on the retina from any artificial illuminant is sufficient to produce injury thereto under any practical conditions.

17. Eclipse blindness, the only thermic effect on the retina of common occurrence clinically, is due to the action of the concentrated heat on the pigment epithelium and choroid, this heat being almost wholly due to radiations of the visible spectrum within which the maximum solar energy lies.

18. The abiotic energy in the solar spectrum is a meagre remnant between wave lengths 295 $\mu\mu$ and 305 $\mu\mu$, aggregating hardly a quarter of 1 per cent. of the total. At high altitudes and in clear air it is sufficient to produce slight abiotic effects such as are noted in snow-blindness and solar erythema, the former only occurring with long exposures under very favorable circumstances and the latter being in ordinary cases complicated by an erythema due to heat alone. The amount of abiotic energy required to produce a specific effect in solar erythema is substantially the same as that required for mild photophthalmia.

19. Erythropsia is not in any way connected with the exposure of the eye to ultra-violet radiations, but is merely a special case of color fatigue, temporary and without pathological significance.

20. Vernal catarrh and senile cataract we can find no evidence for considering as due to radiations of any kind.

21. Glass-blower's cataract often charged to specific radiation, ultra-violet or other, we regard as certainly not due to ultra-violet light but probably due to the overheating of the eye as a whole with consequent disturbed nutrition of the lens.

22. Commercial illuminants we find to be entirely free of danger under the ordinary conditions of their use. The abiotic radiations, furnished by even the most powerful of them, are too small in amount to produce danger of photophthalmia under ordinary working conditions even when accidentally used without their globes. The glass enclosing globes used with all practical commercial illuminants are amply sufficient to reduce any abiotic radiations very far below the danger point.

23. Under ordinary conditions no glasses of any kind are required as protection against abiotic radiations. The chief usefulness of protective glasses lies not so much in their absorption of any specific rediations, as in their reducing the total amount of light to a point where it ceases to be psychologically disagreeable or to be inconveniently dazzling. Glasses which cut off both ends of the spectrum and transmit chiefly only rays of relatively high luminosity, give the maximum visibility with the minimum reception of energy. For protection against abiotic action in experimentation, or in the snow fields, ordinary colored glasses are quite sufficient.

24. So far as direct destruction of bacteria within the cornea or any other tissues of the body is concerned, abiotic radiations possess no therapeutic value. This is due to the fact that abiotic radiations that are able to penetrate the tissues are more destructive to the latter than to bacteria.

Radiant heat. Heat passing through space in vibrations similar to those of light, but of a wave-length that cannot be perceived by the eye.

Radiant point. Any luminous point from which light proceeds.

Radiate figure. That seen, e. g., about the macula in albuminuric retinitis, etc. See, e. g., p. 209, Vol. I of this *Encyclopedia*.

Radiation of Gratiolet. Same as radiations, optic.

Radiation pressure. Pressure exerted by light where it falls, and also on the source of light by reaction.

Radiations, Optical. Optic radiations. A bundle of nerve-fibres in the posterior part of the optic thalamus, continuous with those of the corona radiata, probably the termination of the optic nerve. The fibres are derived mostly from the optic tract and the external and internal geniculate bodies, and radiate into the parietal and occipital lobes. See **Intracranial organs of vision,** p. 6547, Vol. IX of this *Encyclopedia.*

Radioactive lens. See **Lens, Radioactive,** p. 7416, Vol. X of this *Encyclopedia.*

Radiogram. Same as skiagram.

Radiograph. (a) An instrument for measuring and recording the intenstiy of solar radiation. (b) The life-size shadow picture of an object.

Radiographer. One skilled in obtaining radiographs.

Radiography. SKIAGRAPHY. FLUOROSCOPY. ROENTGENOGRAPHY. RADIOSCOPY. The art or process of taking shadow-pictures of an object by the aid of radioactive agents. The term is also used in a restricted sense to designate the process of taking shadow-pictures of human organs and tissues and of pathological products, foreign bodies, etc. in them. See, e. g., **Localization of ocular foreign bodies,** p. 7503, Vol. X; and **Fluoroscope,** p. 5232, Vol. VII of this *Encyclopedia.*

J. H. Fisher (*British Jour. of Ophthalmology,* p. 252, Apr., 1917) very properly says of the paper of Walter Dandy (*Bulletin Johns Hopkins Hosp.,* 37, Nov., 1916) that it is one which should be read by the neurologist, the ophthalmic surgeon and by everyone interested in cerebral surgery.

The very useful plan has been adopted of reproducing the X-ray picture in duplicate. Under each untouched print appears a second picture, in which details lost in reproduction have been intensified. This appears a very practical and absolutely fair way of bringing before the reader features which, although undoubtedly present in the untouched picture, are with difficulty identified in the absence of personal demonstration by the author. A large number of cases deal with variations in the sella turcica, and the authors have proved by autopsy in certain cases, that shadows in or directly above the sella are due to areas of calcification.

A general conclusion is reached that uncalcified brain tumors do not cast shadows unless the tumor tissue has invaded the accessory sinuses, although possibly an exception has to be made in regard to some hypophyseal lesions which are viewed against a dark temporal fossa.

Calcified or bony tumors cast shadows which are readily recognied; such shadows may occur as frequently as in 6 per cent. of all patients with brain tumor. One case of exceptional interest is that of a large aneurism of the internal carotid artery, in which two calcified areas gave shadows in the shape of more or less concentric thin lamellæ. The authors point out that erosion of the sella turcica and destruction of its posterior clinoid processes are not conclusive evidence of pituitary tumor. Such bony changes may be due to the local pressure of tumors arising in an adjacent part, or even to a general increase of intra-cranial pressure arising from cerebral or sub-tentorial lesions; while, on the other hand, pituitary tumor may be present with very little or no change in the sella turcica. These two facts emphasize the necessity for the combined study of clinical and radiographic signs in all cases.

The X-ray work at the Johns Hopkins Hospital has been brought to such a state of perfection that the authors are able to recognize and to illustrate such valuable signs as general enlargement of the skull, allowed for by opening up of the sutures of the calvarium, and thinning with general convolutional atrophy of the skull; and they point out that such manifestations are generally associated with lesions below the tentorium cerebelli, which have induced hydrocephalus, although one such case in their series was due to a suprasellar lesion causing an obstructive hydrocephalus, initiated in the third ventricle. They have also been able to identify in their X-ray pictures such remarkable conditions as calcification in the choroid plexus, calcification in the pineal gland and in the falx cerebri, enlargement of the internal auditory meatus, and the presence of an enlarged intracranial vein and its tributaries.

Radiometer. This instrument consists of four horizontal arms of very fine glass, carefully pivoted so as to revolve easily; the tips of the arms having pith discs blackened on one side. The whole is contained in a glass vessel almost exhausted of air. When exposed to light or heat the arms move around, more or less swiftly according to the strength of the rays. The radiometer was invented in 1873-76 by Crookes.

This term is also used to define an apparatus for measuring the penetrating power of the x-rays.

Radio-micrometer. An apparatus for measuring the penetrating power of X-rays.

Radiophone. Any device for the production or transmission of sound by radiant energy, as a photophone or thermophone. An instrument similar to the photophone, in which a block of vulcanite or of some similar substance is used as a receiver, without a telephone, the vibratory expansion and contraction caused by the heat of the vibrating beam giving out an audible sound. See **Bell's photophone.**

Radiopraxis. Use of rays of light, electricty, etc., in the treatment of disease.

Radioptican. This is an instrument which projects a brilliantly illumined and greatly enlarged image of post card, photograph or object on any white screen. Its chief value is as a means of education, amusement and entertainment.

Radioscopy. The examination of the deep structures of the body by means of Röntgen rays. See **Radiography.**

Radiostereoscopy. The inspection of the interior organs by means of the Röntgen rays.

Radiotherapy. The treatment of disease by such radioactive agents as the Röntgen rays, radium rays, polonium rays, actinium rays, thorium rays, mesothorium rays, etc. See, especially, **Radium in eye diseases,** as well as **Mesothorium,** p. 7660, Vol. X of this *Encyclopedia.* To the matter to be found there the following notes are appended.

With a review of what has been done with radium in ocular therapeutics, Ryerson (*Oph. Year-Book,* p. 37, 1912) records his own experiences. He warns against the danger of its caustic effect upon tissues exposed to its direct action. Except for epithelioma a screen or filter of lead, tin, or aluminum should be interposed to exclude the alpha-rays. He has used a 'square containing 4 mg. of radium bromid and covered with impermeable varnish. This, with the use of a lead filter, can be applied to the lids for one hour. He reports a case of rodent ulcer of twelve years' standing almost completely healed in three months by applications of one-half hour to one hour at intervals of three or four weeks. A tumor of the eyebrow, excised and found to be small-celled sarcoma, recurred within three weeks and grew rapidly. The radium was applied one hour daily for eleven days, when the tumor gradually disappeared. Two further treatments of one hour each were given at intervals of four weeks. After one year there was no sign of recurrence. Ryerson has successfully treated with radium corneal ulcers, including a recurrent vascular ulcer, an extensive sloughing ulcer, and a deep infiltrating ulcer that had resisted other means of treatment. Ryerson also suggests a trial of radium for certain forms of limited lenticular opacity and opacities in the vitreous.

A case of epithelioma of the lower lid, reported by Hirsch, was so extensive that excision would have included the whole lid. It was treated with x-rays, four exposures in as many weeks, and subsequently with radium, applied four times weekly. At the end of eight months there was complete healing with a useful lid and comparatively slight scar. Chalupecky has experimented with water containing radio-active substances. Its injection under the conjunctiva and into the vitreous of rabbits was not followed by suppuration, possibly on account of a bactericidal action. It showed a trace of radio-activity thirty hours after injection. Benedetti has employed preparations of radium bromid in the ordinary vehicles, such as water, glycerin and vaselin, and finds they rapidly cure keratitis caused by the pneumococcus, staphylococcus and diplobacillus. They are beneficial in all forms of conjuntivitis, and have especial value in trachoma. For this disease he used an ointment (also containing copper citrate), and reports among 300 cases 15 per cent. cures in the first month, and 40 per cent. within three months, while 6 per cent. resisted the treatment.

Flemming (*Oph. Year-Book,* p. 31, 1913) applies radium and mesothorium by the following method: The metal is spread on linen in the form of the relatively insoluble carbonate, embedded in paraffin and enclosed in aluminum and gutta-percha in a frame, one side of which is further protected by a layer of lead 1 mm. thick. The normal human eye can be subjected to this radium preparation (3 to 5 mgm.) for 4½ hours intermittently, and for two hours continuously, without permanent disturbance being produced; the corresponding periods for mesothorium being 9½ hours and 45 minutes. Asthenic ulcers of the cornea which had not yielded to other remedies healed rapidly under radium, leaving remarkably little opacity. In serpent ulcer, gonorrheal ulcer, phlyctenular and parenchymatous keratitis, leukoma, and corneal sclerosis, no particular advantage was observed from the use of the metal. In iritis, although pain was relieved, there was no objective improvement. In some cases of trachoma the follicles rapidly subsided, while in others there was no gain after several months' treatment. Small tumors were almost always favorably influenced.

Chalupecky's microscopic studies of tissues subjected to various modes of radio-activity point to the X-ray as the most powerful. This may be due to the fact that the X-ray can be applied directly to the eyeball, whereas radium and mesothorium must act through the lids. The action of mesothorium appears to closely resemble that of radium, although the former is much less expensive. Fusita's studies with frogs showed no change in the retinal tissues after exposure to radium. The corneal endothelium of the rabbit showed vacuolization and structural changes, but there were no alterations in the epithelium of the lens. Radium was found to quickly reduce the follicles of trachoma, but to have little influence on the infiltrating cells.

Rauch insists that for the proper understanding of X-ray therapy every case report should state the strength of current, hardness of tube, time of exposure and distance of the tube from the part treated. A dose which produces erythema is always excessive and injurious in treatment of the eye. Divided doses produce a greater effect than a single radiation or, in other words, a cumulative effect is developed.

Harrison Butler (*Br. Jour. of Ophthalm.*, p. 64, Jan., 1917) has reviewed the paper of Deutschmann (*Zeitschr. für Augenheilk.*. March-April, 1915) on this subject.

He describes a case in which one eye had been removed after an accident. Later, a melanotic growth was discovered in the remaining eye. Rather than excise it at once, Deutschmann decided to try the effect of mesothorium. He obtained a capsule coated with an equivalent of 100 milligrammes of pure mesothorium. The salt was covered with a silver plate, which served as the first filter. A rubber covering acted as second filter. An incision was made in the conjunctiva and a pocket fashioned into which the flat capsule was introduced. It was left *in sitû* for an hour. This treatment was repeated upon several occasions.

Deutschmann described the gradual recession of the tumor. Unfortunately, the patient returned to South America, and nothing further was heard of him. This fact robs the communication of all interest, for most probably he went the way of most cases of unoperated melanotic sarcoma.

Radish. *Raphanus sativus.* Radish, reduced to a pulp and mixed with honey, was a favorite remedy in ancient Greco-Roman times for ecchymosis of the eyelids.—(T. H. S.)

Radium in eye diseases. This is the most characteristic of those substances which possess the property of radio-activity, i. e., have the power of producing photographic, electric and other effects by a process identical with, or analogous to, radiation. The property was first observed in uranium by Becquerel in 1896—hence the name "Becquerel rays." In 1898 Schmidt and Madame Curie discovered almost simultaneously that the compounds of thorium had the same radio-active property; and further elaborate investigations led to the discovery of polonium, radium and actinium, as new substances with radio-active properties. Polonium was the name given by M. and Mme. Curie to the radio-active component of the bismuth separated from pitchblende. Its activity is transient. In the new field of research thus opened up important work has been done by Rutherford, Crookes, Ramsay, Soddy, Huggins, and others.

Radium is derived from pitchblende, in which it exists in very small quantities. After a long-continued process of fractional chrystallization it has been prepared in the form of a tolerably pure salt. Its atomic weight is high, 226.4 according to Madame Curie, who discovered the element in 1902. The process of obtaining the element is very tedious. Thus at Nogent-sur-Marne, France, one to two kilograms of impure radium bromide are procured from a ton of pitchblende residue after processes extending over two and a half months. In 1911 the price of radium salts was $80 a milligram.

When compounds of radium are first prepared they become self-luminous (radiant), glowing in the dark. This luminosity declines gradually in time. Another curious property of radium is that this element is able to maintain itself and matter in the immediate vicinity at a temperature a little higher than that of surrounding matter. At first sight this would imply a contradiction of the second law of thermo-dynamics; but it is possible to explain it as the result of energetic changes going on in the atom. The radium rays also produce effects on organic matter, and certain of these rays may have an influence in destroying malignant tumors.

The most delicate method for studying radio-activity is electrical, depending upon the property the rays have of ionizing the air and rendering it a conductor of electricity. When, for example, the rays are allowed to pass in the neighborhood of the plate of a gold-leaf electroscope, the latter rapidly loses its charge. In this respect the rays are similar to the Röntgen rays. By means of elaborate forms of apparatus made on this principle it has been established that uranium, thorium, and radium give off (at least) three distinct kinds of rays. These have been called the α, β and γ rays. The α rays have been proved to be positively charged particles of mass about twice that of the hydrogen atom, projected with a velocity comparable with that of light. The β rays are known to be negatively charged particles identical with the cathode rays in a vacuum tube, the mass of each negatively charged particle being about the thousandth part of the mass of a hydrogen atom. The γ rays, which are very penetrating, are similar to the Röntgen rays, and are probably in the nature of disturbances in the ether.

Radium and thorium have a further property—viz., the power of exciting in neighboring bodies the same radio-active power; which, however, exists only for a time. This is due to a material emanation which has all the properties of a gas in very small quantities. According to the observations of Ramsay and Soddy, the radium emanation, if preserved, changes gradually into helium—or at any rate the spectrum of the substance shows in time increasing traces of helium.

These and many other facts suggest that the atoms of radium and the other radio-active substances are in process of disintegration; and this view has been elaborated into a fairly consistent theory. The theory is based upon the general statement that the radio-activity of radium, thorium, and uranium is maintained by the continuous production of new kinds of matter which possess temporary activity. The emanations which are characteristic of thorium and radium are the result of the production of this matter. Radio-activity is mainly due to the *a* rays which ultimately become absorbed. These rays are streams of positively charged particles projected from the body, probably the positively charged portions of neutral atoms, or at least what is left of the neutral atom when one negative electron has been driven out of it. The ß rays are composed of the negatively charged particles or electrons. The high velocity with which these rays are projected betokens a remarkable transformation of energy, and explains the production of heat in bodies in the vicinity. The fact recently established by Rutherford, that the heating effect and the radio-activity as measured by the *a* rays follows much the same law as regards their behavior under varied conditions, shows that they are comcomitants of the same series of material changes.

Radio-activity has been discovered in certain mineral waters and deep wells, and is probably possessed, though in a very minute degree, by other substances than those which are conspicuously radio-active. Thus freshly fallen snow and freshly fallen rain, when evaporated to dryness, leave a radio-active residue. The fact that the phenomenon is strongly marked in substances with high atomic weights indicates a comparative instability in such complex atoms; and the breaking up of these complex atoms must mean the final disappearance of the radio-active substances as chemical elements. In their place will be found ultimately the inactive constituents of the emanations, such as argon or helium. *(Standard Encyclopedia.)*

Wm. J. Schieffelin in a paper read before the Am. Pharmaceutical Soc., Aug. 25, 1914, remarks that the energy resulting from the resolution of an element into its constituent parts is vastly greater than that resulting from chemical combination. The largest amount of energy released in any known chemical reaction is from the combination of equal volumes of hydrogen and oxygen to form water, but the emanation of radium, in its successive transformation, accompanied by the expulsion of alpha rays, yields more than ten million times as much energy. Ninety-five per cent. of the energy in the radiation from radium and its subsequent products is in the form of the alpha radiation, a corpuscular radiation in which the corpuscles or alpha particles are positively charged helium ions.

A milligram of radium expels 136 million separate alpha particles per second, which are made visible in a spinthariscope. The alpha rays emitted from one three thousand millionth of a grain of radium can be detected by the gold-leaf electroscope. The rays are given out uniformly in all directions in the form of continuous volleys of tiny projectiles travelling at a rate of 12,000 miles per second. Their range is nearly three inches in air and many yards in a vacuum. They are not penetrating, being absorbed by thin sheets of aluminum, paper or glass. Only a small fraction of the alpha particles is set free, unless the radium salt is spread out so as to present the largest possible surface.

The emanation is a gas, which in turn, steadily disintegrates into alpha particles and radium A, from which in the same way come radium B, C, D, E, and F in succession. It is from these products, especially in radium C, that the beta and gamma rays are given off. The beta rays are electrons of negative electricity, the same as the cathode rays, except that the velocity of the beta particles is much greater, approaching the velocity of light, 186,000 miles a second.

The gamma rays are not considered to be particles of matter, but are waves in the ether similar to the X-rays. They are far more penetrating than the alpha and beta rays, and are used in the external application of radium in cancer, the others being easily excluded by thin metal filters.

The emanation has an atomic weight of 222, and a characteristic bright line spectrum. It belongs in the group of inert monatomic gases with helium and argon. It is not absorbed by any known reagent and shows no power of chemical combination. The emanation is 100,000 times as active, weight for weight, as radium. Like other gases, it can be collected, confined and handled in ordinary glass containers. This is usually done only when it is mixed with enormously greater volumes of air or other gases. Like other gases, the radium emanation is somewhat soluble in water. It disintegrates at the rate of one-half in about four days, and since the radioactive products into which the emanation disintegrates decay at the rate of one-half in a few minutes, it follows that the total radiation from the emanation and the subsequent disintegration products decreases at the same rate as the emanation, namely one-half in about four days.

When water with emanation in solution is left in an open bottle the emanation diffuses out, and if the water is shaken up or otherwise disturbed the process of diffusion of the emanation is accelerated. From 10 to 30 per cent. of the emanation in solution in water may be lost by pouring from one vessel to another.

The strength of radioactive water is usually expressed in Mache units per litre. Radioactive water of 2,700 Mache units contains per litre as much emanation as is emitted in thirty days by one microgram of radium (1 Mache unit equals 0.001 electrostatic units, one of which equals 3.33 by 10^{-10} amperes). The radioactivity of water is measured by fontactoscope, which is an electroscope with a chamber for ionized air and a scale for measuring and timing the discharge. The instrument is standardized by first testing a solution of a known amount of radium chloride which has been sealed thirty days. Great care must be used in sampling the water.

Water is charged either by dissolving the soluble bromide or chloride of radium or by submerging the insoluble sulphate. The latter is more economical, but the sulphate must be in a minute state of sub-division and must present the largest possible surface. There are several ways of accomplishing this: First—Precipitating the sulphate on asbestos and placing it in a porous cell. Second—Mixing it with charcoal and forming into slabs. Third—Mixing it with cement and forming balls. Fourth—Mixing it with clay and firing it, forming terra cotta.

Most of these processes are protected by patents. The advantage of using an insoluble salt is that it can be employed repeatedly and its use continued indefinitely. The terra-cotta rods can be used eighteen hundred years and still have half their radium content available.

Moreover, they avoid introducing into the organism a permanent radio-active body, as is done if a soluble salt is administered.

While a given amount of radium always emits a constant and uniform amount of emanation, the proportion given out by an insoluble salt depends upon its state of sub-division. In the insoluble salts most of the emanation is occluded by the salt itself; in compact form the sulphate will only yield two and a half per cent., while if it is finely powdered and divided so that it presents a large surface, ten per cent. can be obtained.

A uniform strength of emanation is obtained when the same amount of radium sulphate is held in the same state of sub-division, submerged in the same volume of water for the same length of time.

If it is desired to prepare doses of 100 Mache units, and the sulphate can be held in such a state that ten per cent. of its emanation is available (as is the case when distributed through porous terra cotta) it will be convenient to use an amount of radium which would yield 2,000 Mache units and submerge for four days in tightly closed containers, when one half of ten per cent. or 100 Mache units will be obtained.

The stronger natural springs contain from one to two hundred Mache units per litre, with which they are charged while flowing over radio-active minerals or passing through cavities where the emanation has collected. The reason why many mineral waters when drunk at the springs give therapeutic results unattainable when they are bottled and transported, is the speedy dissipation of the fugitive emanation, which is reduced to one-half in four days unless there is a source for its renewal. The means of renewing the radio-activity of bottled waters, or of charging any water with emanation, are afforded by the above mentioned devices, and the physician may prescribe a drinking cure which can be carried out with precision in the patient's home.

The chief effect of the radiations from radium and its disintegration products is to produce an ionization of the atoms of whatever substance the rays penetrate. Chemical effects follow as a secondary result of the ionization. Von Noorden and Falta say that in contradistinction to all other forms of electro-therapy, we possess in the radio-active substances a means of carrying electrical energy into the depths of the body, and there subjecting the juices, protoplasm and nuclei of the cells to an immediate bombardment by explosions of electrical atoms. We may therefore designate this internal treatment with radio-active substances, internal electrotherapy.

The employment of radium and its salts in ophthalmic therapeutics has been to some extent treated under **Radiotherapy.** To the matter found there and under similar captions are added the following observations.

An early use of radium was reported by Thiebault (*La Clinique Ophtal.,* Dec. 10, 1906) who in 1886 removed a crust-covered ulcerous growth about the size of a lentil. In 1892, when the disease was apparently arrested, a new lesion appeared in the shape of a dermic hypertrophy which two years later rapidly ulcerated. This ulcer was cured by galvanocautery. Another attack occurred in 1898, which was cured; but again recurrence of the disease took place, the growth involving not only the skin, but the orbital muscle, tarsus and the mucosa also. This was cured by radiotherapy, but a return of the lesion occurred in six months. Thiebault now made 229 applications of radium of an average duration of 30 minutes each successfully; and the patient got into the hands of empirics. A second case, one of facial epithelioma with preauricular lymphatic enlargement, was cured by eight applications of the radium. Thiebault reports also two cases of episcleritis cured by radium. He has also had success with radium in the treatment of trachoma.

At the July, 1909, meeting of the Ophthalmological Society of the United Kingdom Arnold Lawson said that cases for experiment with radium had been selected from the out-patient clinic of Moorfields Hospital, and were selected as instances of maladies which usually proved obstinate, or only improved slowly under the ordinary forms of treatment, or else were of an active or virulent nature and so required drastic measures. Only 17 cases had so far been tried, but in every case the result of exposure to radium had been very encouraging. Most of the cases were corneal ulceration, four were non-ulcerative lesions, and one was episcleritis. After one application of five minutes to a hypopyon there was distinct benefit. For instance, a man aged 35, gave a history of injury to the right eye; there was deep ulceration with grey infiltration of an area of 4 mm., with a large hypopyon; twenty-nine milligrams of radium were applied for five minutes and five days later the injection subsided and the hypopyon had disappeared—two days after a second application of three minutes the man was discharged from the hospital, the eye being not quite white, but, for all practical purposes, well. Other cases also did very well from the treatment. In all instances the only other measures used were boric lotions and atropin. Some punctate erosions were similarly treated, and gave equally encouraging results, as did cases of old standing trachomatous pannus, except in one case, in which there was increased vascularity after the treatment. The dosage of radium was an important point; a small dose of 5 mg. seemed to act as quickly as did a much greater quantity. In one case the pain after the application endured for three days, but in the others the longest time was twenty hours.

The radium was applied in sealed glass tubes, the glass cutting off the alpha rays, so that the beta and gamma rays only passed through the lesion.

Jose G. del Mazo (*Archivos de Oftalmologia,* Sept., 1911) gave the history of a patient, aged 54, with a small growth on the lower lid for twelve years. This had remained stationary for ten years, and had then grown rapidly, following repeated cauterizations with nitrate of silver. A large tumor was dependent from the lower lid and ala of the nose. There was almost continuous hemorrhage and the patient's general condition was deplorable. The preauricular and submaxillary glands were enlarged. After a microscopic diagnosis of pavement epithelioma had been made, applications of radium (nine centigrams of the bromide) were instituted. These were given almost daily and lasted for from fifteen to twenty-two hours each. The eye was protected with lead. Treatment was suspended several times on account of marked local reaction and fever. In all, the treatment was used for 228 hours. The eyelashes fell out, but grew again. The lens subsequently became cataractous. Cure of the tumor was, however, complete, with but little scar; and after nine months the general health was good, and there was no sign of recurrence.

C. H. May (*Ophthalmology*, July, 1912) to test the value of radium in trachoma used celluloid plates coated on one side with a film of radium bromid, having a radio-activity of 25,000, protected by a layer of water-proof varnish; the plates were shaped like the solid blade of an entropion forceps, so that the broad or coated end could be readily applied to the trachomatous surface of either the upper or lower lid, and the celluloid itself might act as a protection to the eyeball.

The method of application was the following: After or without previous local anesthesia, the broad radium-coated end of the instrument was inserted beneath the upper lid of one eye, the radium coating pressed against the granulations, the patient then holding the plate in position; at the end of ten minutes the plate was transferred to the lower lid, with the radium coating next to the granulations; thus the treatment consumed twenty minutes for each eye. Possessing four of these plates, several patients could be treated simultaneously. The radium treatment was applied to the right eye in each instance, and, by way of control, the left eye was treated in the usual manner with sulphate of copper. The plates always gave rise to discomfort, even when the eye had previously been anesthetized, causing irritation, lachrymation, and sometimes pain; this may have been due to the mechanical effect of the plate pushed between the lid and the eyeball.

Fifteen patients were treated in this manner. Four were old cases of trachoma with beginning cicatricial changes, without pannus; four represented the cicatricial stage in great part, with more or less pannus; two were of the large "frog-spawn" variety; three were examples of ordinary trachoma of moderate severity with no cicatricial development, and two represented the so-called mild trachoma type in which there was room for difference of opinion as to whether they were real trachoma or merely catarrhal conjunctivitis with follicular enlargement.

In seven cases the treatment was continued three months; in one case four months; in two cases five months; in three cases six weeks; in two cases two months; the radio-activity was 25,000; the exposures were repeated every two or three days and lasted ten minutes for the upper lid, and ten minutes for the lower lid; some of the cases were observed for long periods after discontinuing the treatments.

In no case was the result of the treatment with radium as good as obtained with sulphate of copper; radium exercised a favorable influence upon the condition, but the left eyes treated with sulphate of copper improved more rapidly than the right eyes, which were exposed to radium; in every instance the patient complained more of the irritation of the radium plates than of the bluestone.

Used in the form of radium-coated celluloid plates, the results obtained in the treatment of trachoma did not warrant the adoption of this remedy in place of other means which are more or less satisfactory. It may be argued that had the radium been used in more concentrated form in glass tubes, the results might have been better and more in conformity with the reports of those investigators who have been favorably impressed with the action of this remedy; but there are a great many difficulties associated with the use of radium in concentrated form in glass tubes, and when these drawbacks were removed, by using coated plates, the results were less satisfactory than those obtained with the stick of sulphate of copper.

Treacher Collins (*Oph. Review*, p. 187, June, 1909) described a case in which an epibulbar epithelioma completely disappeared after the application of radium bromide. A man, æt. 80, had a new-growth about 10 mm. in diameter at the limbus in his left eye. It had formed in two years, and was gradually increasing in size. A small piece was cut off, and microscopical examination showed it to be an epithelial growth, which was extending into and infiltrating the episcleral areolar tissue. At the Radium Institute the patient had 10 mg. of radium bromide on a circular disc 1 cm. in diameter, unscreened; it was held continuously over the growth for fifty minutes by a relay of assistants. After this the growth gradually disappeared. At the end of a fortnight only a thickening at the margins was left. Five months since the treatment all that could be seen at the site was a smooth greyish scar.

McKenzie Davidson and Arnold Lawson (*Oph. Review*, p. 181, June, 1909) report the cure of a case of spring catarrh by radium. The patient was first seen in April, 1905, suffering from lachrymation and slight conjunctival discharge which had lasted nearly a year. On examination, there appeared the typical, flat-topped elevations of spring catarrh scattered in great numbers all over the palpebral conjunctiva, with a good deal of reddening and some viscid discharge. The bulbar conjunctiva was healthy, there was no pain, and the cornea was quite clear, but the irritability was most marked in the morning. Eosinophile bodies were found in great abundance in the conjunctival secretion. The treatment at first adopted of complete rest for the eyes, with 4 per cent. yellow oxide of mercury ointment, only made the condition worse, so that 2 gr. to the ℥i copper drops were substituted, which appeared to give considerable relief for a time. Four months later, after a visit to the seaside, there was great exacerbation of the symptoms, but the condition responded again to treatment, so that there was a temporary improvement until January, 1906.

As there appeared no sign of the catarrh yielding to the methods of treatment so far employed, it was decided to try cautiously the effect of radium; and at first the left eye, being the worse of the two, was subjected to exposure while the right eye was left alone. In all, eight sittings were given between February 6, 1906, and January 9, 1907, both eyes being treated except on the first occasion; 44 milligrams of radium being applied for periods varying from 5—15 minutes, generally the latter. The condition began to show immediate signs of improvement, and at the end of the time stated both conjunctivæ were perfectly cured, and all the enlarged pupillæ had completely disappeared. During the whole of 1907 the boy was kept under observation and went to school as usual. He was last seen on January 12, 1909, when no trace of recurrence was visible; there was slight irregular coloration of the conjunctiva, and that covering the tarsus was yellowish-white and bloodless. Judging from the few cases which he had treated in this way Lawson considered that more successful results followed few sittings and a comparatively large dose of radium, rather than frequent sittings with a smaller dose of the salt. See, also, **Vernal conjunctivitis.**

A danger from the use of radium in a varnish, placed upon the skin for angioma, cancroid, or eczema, was pointed out by Courmelle (1909). In the case of an infant a piece of the varnish became detached, and might have resulted in a very serious burn had it remained long within the conjunctiva.

Roselli has used radium without meeting with the slightest reaction in the tissues of the eye.

Almann in the treatment of cancer with radium has met with irritation which disappeared when the application was suspended for two or three days. The duration of the treatment was three or four months. The deeper parts of the tumor were not influenced by the applications.

If we are to believe Matagne (*Ann. de la Policlinique Centrale,* Nov., 1912) eczema, angioma, nævus, lupus and malignant tumors of the eyelids, as well as trachoma, spring catarrh, pterygium, and epithelioma of the conjunctiva, to say nothing of ulcers of the cornea and leucomata, are all favorably influenced by radium.

Edward Heckel (*Arch. of Ophthal.,* Sept., 1916) reports a case of melanosarcoma of the orbit in a man aged 48 years. The orbital growth followed an enucleation of the eye for a melanosarcoma. Incision was made into the orbit and fifty-three milligrams of radium element, in a silver capsule and screened by lead and a rubber tube, was inserted and left for eleven and one-half hours. Eight months later there was slight recurrence and an application of fifty-three milligrams of radium was made for twelve hours. Six months later the orbit was curetted and one hundred milligrams of radium was inserted and left in place for fourteen hours. Ten months later there was no pain or discomfort in the orbit and no increase in the orbital contents. There was, however, an extensive involvement of the liver, spleen, and pleura.

The author believes that an electro-cautery knife could preferably be used to remove the mass from the orbit and then introduce one hundred milligrams of radium element and allow it to remain twelve hours.

W. H. Jessop (*Trans. Ophthal. Soc. U. K.,* p. 245, Vol. 36, 1916) gives the history of a man, aged 55, who had been engaged in X-ray work for many years, and had in consequence lost all the fingers of one hand. He developed a swelling towards the centre of the left upper lid, 1 cm. in diameter and 0.5 cm. in height. The growth ulcerated from time to time. It was diagnosed by the writer as an epithelioma. It had been treated without success with glacial acetic acid and the actual cautery, and excision had been recommended. Jessop removed the accessible portions of the growth, and 10 mg. of pure radium bromide was applied, without a screen, for one hour. There was marked reaction. No recurrence in two months. See, also, **Radiotherapy.**

Radius. A semidiameter; one of a number of lines extending from a centre.

Radius, Justus. A well known German ophthalmologist, who in later life abandoned ophthalmology and devoted himself almost exclusively to hygiene and pharmacology. Born at Leipsic, Nov. 14, 1797, he received his medical degree (at the University of Leipsic) in 1822. After a number of scientific journeys, he settled in Leipsic, and became extraordinary professor of ophthalmology at the University in 1825. He had an extremely large ophthalmic practice, but never completely abandoned general medicine. In 1872 he celebrated the semi-centennial of his doctorate, and, in 1882, the 60th anniversary of that dignity. He died Mar. 7, 1884.

Radius's ophthalmologic writings are as follows:

1. *Scriptores Ophthalmologici Minores.* (3 vols., Leipsic, 1826-1830.)

2. *Handwörterbuch der Gesamten Chirurgie und Augenheilkunde.* (6 vols., 1836-1840. In conjunction with Walther and Jaeger.)

3. Ueber die Sogenannte Agyptische Augen-Entzündung und deren Jetzige Behandlung in England. (*J. d. Chir. u. Augenh.* von Graefe und Walther, V, 297-304, 1823.)

4. Ueber einige Augenkrankheiten, die Vorzüglich häufig in England Vorkommen. (*Ibid.*, VII, 370-389.)—(T. H. S.)

Radius of curvature. The radius of the circle of curvature.

Radix nervi optici. (L.) The optic tract.

Raggi. (It.) Rays.

Ragle. (F.) A visual hallucination (mirage) observed by French troops while marching through the desert, in which water, prairies and even ghosts were imagined to be seen. It was generally caused by isolation and insomnia, and was followed by delirium.

Rag weed. See **Pollantin,** p. 10306, Vol. XIII of this *Encyclopedia.*

Railroad employees, Examination of the eyes of. See **Eyes of soldiers, sailors, railway and other employees, Examination of the,** p. 5038, Vol. VII of this *Encyclopedia.*

Railroad coach lighting. This subject is treated in a most practical manner by the *Electrical World,* p. 879, Nov. 1, 1913. Extensive and carefully conducted tests on day-coach lighting were made under the auspices of the committee on illumination of the Association of Railway Electrical Engineers. Tests on the lighting of various interiors afford a striking commentary on the inefficiency of certain very common methods of steam railway car lighting as compared to the efficiency of other methods which are better in appearance and more comfortable to the passengers. With test results reduced to an equal basis of 66.6 lumens per running foot of car, there was a difference between the systems tested ranging from 2.42 ft.-candles for the most efficient translucent reflector equipment down to 1.03 ft.-candles for the least efficient of the lamp equipments tested.

It is gratifying to know that the bare lamp which obtrudes itself so atrociously in the vision of passengers on many cars is next to the bottom of the list in efficiency. Since it is both inefficient and uncomfortable, railway managements can no longer have excuse for continuing its existence. The standard square diffusing shade regularly used in sleeping cars also makes a very poor showing with only 1.35 ft.-candles. This equipment has always afforded a striking example of lack of attention to illuminating engineering with consequent loss of money to the operating company and a loss of illumination for the use of the passengers in such cars. Clear prismatic reflectors head the list of 2.42 ft.-candles, with heavy density opal reflectors a close second at 2.14 ft.-candles. The latter, on account of their ease of cleaning when of proper design, should find extensive use in railway car lighting. As might be expected, the highest efficiency was always obtained with bowl-shaped reflectors open at the bottom. All attempts to close the bottom of such reflectors with diffusing bowls have been unsatisfactory on account of the decided loss of efficiency.

The tests show that there is no practical difference in the measured illumination obtained with the center-deck and side-deck systems of lighting. In the center-deck system the lamps are placed in a single line along the center of the car. In the side-deck system one row of lamps is placed over each row of seats. However, the center-deck system has important advantages in lower cost of lamp renewals and cleaning and the use of larger and more efficient lamps. To avoid bad shadow effects it is found that lamps must be spaced opposite every two pairs of seats with either system where direct lighting is employed. With indirect or semi-indirect lighting, which, of course, is applicable to only the center-deck system, the spacing can be every three seats. It is interesting to note that both these latter systems in the tests gave higher efficiency than did the bare lamp. Thus, the most comfortable system for the eye under these specific conditions consumes less electricity than the most uncomfortable system. With such authoritative results before them, American railway managements can no longer have an excuse for the continuance of the inefficient lighting arrangements that have been too common in the past. The facts of the matter are that details of car-lighting fixtures in the past have too frequently been determined in an offhand way with the minimum of consideration by some official of a railroad who is unaware of the great differences in comfort and efficiency with the different lamp and reflector equipments available. It is a condition similar to that formerly existing in other fields of illumination. Fortunately, adequate excuse for the continuation of such conditions is rapidly vanishing.

Rainband. A band of the solar spectrum, due to the presence of water-vapor in the atmosphere, and specifically that band made up of the lines of wave-lengths, 6,020 to 5,840 microns situated on both sides of the D line. Attempts to foretell rain, based upon the fact that in the intensity of this band depends on the amount of vapor in the atmosphere, have been made by means of the spectroscope, but have proved unreliable, the rainband being only one of the conditions precedent to precipitation. See Upton's *Use of the Spectroscope in Meteorological Observations, United States Signal Service Notes No. 4* (1883).—*(Standard Encyclopedia.)*

Rainbow. The rainbow is the best known of all optical meteorological phenomena, consisting of a colored arch formed opposite the sun on falling raindrops, and visible whenever the necessary conditions of a passing shower on one side and a clear and not too high sun on the other occur. The colors are always arranged in the definite spectral order, viz., red, orange, yellow, green, blue, indigo and violet, but shade imperceptibly into each other. The cause of this breaking up of sunlight into its constituent colors is the prismatic action of the rain drops themselves. See **Spectrum.**

Intersecting rainbows have frequently been seen. When the sun is reflected from a surface of still water a bow is formed by the reflected image as well as by the sun itself. Lunar rainbows often occur, but the feebleness of the moon's light usually prevents any colors being observed. There are many popular weather prognostications connected with rainbows, all dependent on the fact that they imply local passing showers.

Rainbow quartz. An iridescent variety.

Rainy, George. A well known Glasgow ophthalmologist, son of Harry Rainy. He was born in 1832, in 1868 became surgeon at the Glasgow Eye Infirmary and professor of ophthalmology at the University. He died in 1869.

Rainy's ophthalmic writings are as follows:

1. *On the Theory of the Ophthalmoscope.* (London, 1860.)
2. Ophthalmic Cases. (*Ophth. Rev.,* III, 1867.)
3. Parallactic Movements of the Ophthalmoscopic Image. (*Roy. Lond. Oph. Hosp. Rep.,* III, 91.)—(T. H. S.)

Rainy, Harry. A well known Scotch surgeon, who devoted some attention to ophthalmology. Born in Sutherlandshire, Scotland, in 1792, he studied at Glasgow, Edinburgh, and Paris, finally settling as physician in Glasgow. In 1828 he became surgeon to the Glasgow Eye Infirmary, in 1844 consulting surgeon, and in 1867 physician. He also lectured at the Glasgow University on physiology and practical therapeutics. George Rainy was his son. Harry Rainy died in 1876.—(T. H. S.)

Ramazini, Bernardini,* was born at Capri in November, 1633. He was appointed professor of the theory of medicine in the University of Modena about the end of the seventeenth century. While there he wrote an interesting "*Treatise on the Diseases of Tradesmen,*" which he published immediately after being installed as Professor in the University of Padua. He died of apoplexy in November, 1714.

His work was translated into English by Dr. R. James, and published, along with a translation of a pamphlet on "*Endemial Distempers,*" by Frederic Hoffman, Physician to the King of Prussia. The second edition of the English translation appeared in 1740, and the full title of it is as follows:

Health Preserved,
IN TWO
TREATISES.

I. On the Diseases of ARTIFICERS,
which by their particular Callings
they are most liable to.
With the Method of avoiding them, and their
Cure.
By BERN. RAMAZINI, M.D.
Chief Professor of Physick at Padua.

II. On those distempers, which arise from
particular Climates, Situations, and
Methods of life.
With Directions for the Choice of a healthy Air,
Soil and Water
By FREDERICK HOFFMAN, M.D.
Physician to the present King of Prussia.

Translated and enlarged, with an Appendix,
By R. JAMES, M.D.
Author of the Medicinal Dictionary.

The SECOND EDITION.

LONDON:
Printed for JOHN WHISTON, at Mr. Boyle's Head, and
JOHN WOODYER, at Cæsar's Head, both in Fleet-
Street, 1750.

James has gone through Professor Ramazini's book, and culled practically everything bearing on the eyes. He believes this work to be one of the earliest dealing with occupational diseases, and it is remarkable in its wide scope and thorough description. It is quoted in a treatise by C. Turner Thackrah, of Leeds, published in 1832, and entitled *"The Effects of Arts, Trades, and Professions."*

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* This article, which appears in "*The Ophthalmoscope*" for June 1, 1916, at p. 290, is so extremely interesting that it here is reproduced *in toto.*—(T. H. S.)

The first chapter deals with "Diseases of Metal-diggers."

Ramazine thinks that as the eyes are often injured by mineral steams, the mineral kingdom must likewise be consulted for a remedy.

By the use of internal minerals, Horstius cured an ophthalmia arising from metallic fumes, and eluding all external remedies. But at the same time collyria made of the scales or offal of brass are much recommended; even the ancients were apprised of their virtue; for it is asserted by Macrobius, that those who work in brass mines have always strong and sound eyes, by reason of the drying virtue, as he calls it, that is inherent in the brass.

With the same view does Homer give the brass the original Greek title, and Celsus allows the preference before all others to Cleon's collyrium of the scales of brass, with saffron, and spodium or putty. To these collyria you may add nitre, for Pliny affirms that in saltpetre mines the workmen are not weak-eyed, and the observations of later authors confirm his testimony. Upon the whole, we may lay down this for a standing truth, that the most proper and effectual remedies for defeating metallic diseases are generally to be obtained from the mineral kingdom; and, indeed, the conduct of nature in this point is very provident in furnishing a cure from the same quarter which produces the disease.

In his chapter "Of the Diseases of Gilders," he says: I had occasion myself not long ago to see a young man, a gilder, who died after two months confinement to his bed, having taken too little care to avoid the mercurial exhalations. For they threw him at first into a cachectic habit of body; after that his face became wan and of a cadaverous complexion, his eyes swelled, his breathing became difficult, his mind stupid, etc. And after all, this man died without any feverish symptom.

Fernelius, in like manner, mentions the case of one whose brains melted and ran out of his eyes for several years without a fever; and who died at last, but had formerly suffered a mercurial inunction. And the same author ingeniously acknowledges that he could not but wonder how it came about that this man was never feverish. But in his second book, he seems to offer some reason why mercury quells a febrile heat.

In Chapter iii he treats of the "Diseases of Surgeons," and others employed in friction and inunction for venereal cases.

Frambesarius acquaints us that a surgeon, upon anointing a pocky person with the usual ointment, was seized with a continual vertigo and dimness of sight.

Ramazini then proceeds: For my part, I can think of no cautionary method so proper and so effectual for those employed in such inunction, as that of a surgeon of our country, who finding to his cost that the danger and trouble he underwent surpasses the profit, and having experienced by frequent looseness, gripes and salivations, upon his own person, that such inunctions were more afflicting to him than to the persons anointed, did thereupon alter his course, and continuing to prepare the mercurial ointment as before, and to stand by the patient while the friction was performed, ordered the patients to rub themselves with their own hands; by which means a double advantage is gained; for not only the surgeon avoids danger, but the patients thus heating themselves by the motion and exercise of their arms, make the ointment penetrate the better; and withal have no reason to apprehend any danger to themselves from the remedy, in which they place all their hopes of relief.

Dr. Ramazini deals with the "Diseases of Chemists":

Though the chemists boast of the art of subduing and fixing all minerals, yet they themselves cannot escape free from their pernicious influence; I was acquainted myself with our Carolus Lancelotus, a chemist of some note, but a trembling, blear-eyed, toothless, short-breathed, rotten fellow, whose very looks derogated from the fame and repute of the cosmetic medicine which he used to sell.

"On the Diseases of Potters." Those who sit at the wheel, and form the vessels by turning it about with their feet, are apt to have a swimming in the head, if their eyes are otherwise weak; and often the over-tiring of their feet makes them subject to the sciatica, etc.

In Chapter ix there is a dissertation of the diseases of such as work upon "Brimstone." As sulphur answers the convenience of life in several instances, so it causes no slight disorders in those who boil or melt it, or make use of it in their work. Those who use melted or kindled brimstone fall into coughs, hoarsenesses, shortness of breath, and a running in the eyes.

The analysis of sulphur shows that it consists of double substance, one pinguious and inflammable, and the other acid and apt to extinguish fire. Now when sulphur is melted over a fire, and much more when it is kindled, this volatile acid arises in fumes which being received at the mouth, give rise to the above-mentioned disorders, and particularly to the cough and soreness of the eyes; for the soft and tender structure of the lungs and eyes is signally injured by the pungent acid.

Daily experience vouches that blacksmiths are likewise blear-eyed; which, as I imagine, is not so much owing to the violence of the fire upon which their eyes are almost always fixed, as to the sulphureous effluvia which exhale from the hot iron, and strike or twitch the membrane of the eyes, so as to cause an expression of lymph from their glandules, with a blearedness, and often an inflammation or ophthalmia. It stands in the records of time that Demosthenes's father was a blacksmith; and him, Juvenal describes as being blear-eyed. However, there being a great quantity of sulphur lodged in the substance of the iron, it is no wonder that, while the iron is fining, the thin, sulphureous particles fly out both from the iron and the fire, and, like sharp stings affect the membranes of the eyes, so as to cause sharp rheums and inflammations. I have met with many blacksmiths who complained of such disorders, for which I used to prescribe the application of milk and barley water, and such like temperating things; and bleeding, if the inflammation be great.

New lime, just taken from the lime-kilns, burns and exerts a fiery force. Besides, there is nothing which, after burning, retains the seeds of fire, longer than lime-stone; for if you keep it a year in a dry place, and then dilute it with water, it smokes and exerts the latent fire in setting the water a boiling. In progress of time, as it smoulders and grows old, it loses a great part of its igneous force, and consequently is then less hurtful to the workman; though it always retains a corrosive acrimony which stimulates the throat and eyes, and makes the voice rough, but is easily repulsed and subdued by drinking cold water, and the emulsions of melon seeds and the cold seeds.

Chapter xiv is entitled—"Of the Diseases of the Cleansers of Jakes."

I am here in some doubt whether the physicians, who value themselves upon a neat and clean appearance, will not take it ill, that I carry them from the apothecaries' shop, which smells for the most part of perfumes, and where they deal as in their own province, to take a view of the houses of office. But considering they do not think it beneath them daily to inspect the excrements of the bladder and the belly, in quest of the disorders of the body, they ought likewise to allow of the inspection of these places, where such excrements are laid; and so give us leave to take a view of the diseases of those who are employed to cleanse them.

Since therefore, in our present age, medicine is reduced to the principles of mechanism, I shall not be ashamed of an acquaintance with the states and conditions of the meanest tradesmen, having nothing more at heart than the discovery of the truth. The accident, from which I took occasion to write this treatise of the diseases of tradesmen is as follows:

In this city, which is very populous for its bigness, and is built both close and high, it is usual to have their houses of office cleansed every third year; and, while the men employed in the work were cleansing that at my house, I took notice of one of them who worked with a great deal of anxiety and eagerness, and, being moved with compassion, asked the poor fellow, why he did not work more calmly and avoid overtiring himself with too much straining? Upon this the poor wretch lifted up his eyes from the dismal vault, and replied, "That none but those who had tried it could imagine the trouble of staying above four hours in that place, it being equally troublesome as to be struck blind." After he came out of the place I took a narrow view of his eyes, and found them very red and dim; upon which I asked him, if they had any usual remedy for that disorder He replied, their only way was to run immediately home, and confine themselves for a day or more to a dark room and wash their eyes now and then with warm water; by which means they used to find their pain somewhat assuaged. Then I asked him if he found any heat in his throat and difficulty of respiration, or headache? And whether the smell affected their nose, or occasioned a squeamishness? He answered that he felt none of those inconveniences; that the only parts which suffered were the eyes and that if he continued longer at the same work, without interruption, he should be blind in a short time, as it had happened to others. Immediately after that he clapt his hands over his eyes and run home.

After this I took note of several beggars in the city, who, having been employed in that work, were either very weak-sighted, or absolutely blind. Now I do not wonder that the tender structure of the eyes is offended by such an ugly exhalation.

Ballonius relates the case of a poor workman, at Paris, who had sore and weak eyes, the cause of which he imputes to his trade, for he used to cleanse the streets from dirt. But I ever was, and still am at a loss to form a solid reason why the eyes are the only parts that suffer in such cases, and how the soft textures of the lungs escape, as well as the brain, which one would think might easily be affected by the steams reaching the nostrils.

I am of the opinion that the steam arising from such places, when stirred, is a volatile acid. And yet only the eyes are affected by such effluvia. I doubt if the curious will be satisfied with this solution of the matter—that as some poisons bear a peculiar antipathy to certain parts of the body, cantharides to the bladder, and the cramp-fish to the nerves, so these steams arising from the human ordure, after three years lying, assume a particular nature which injures the eyes only, and is inoffensive to the other parts.

For my own part I cannot rest satisfied in this solution, and therefore do not offer it as an argument of due weight and solidity.

He then produces arguments which lead him to the conclusion that there are special irritants which act where the serum of the blood alone is not their vehicle, but where also phlegm, the blood, and the pituita, which mixture pall their force. In pursuance of this notion it may be more reasonable to offer that the steam of the jakes do with their thinnest and sharpest particles gall the eyes, these being the most obvious parts, and possessed of the most exquisite sense; and thus forcing out the lachrymal juice, join with it so as to form a new substance which is noxious only to the eyes, and not to the other parts which do not afford the like juice.

Whatever be the cause and manner of these steams, by which they affect the eyes more than the other parts, it is certain that the eyes are, by their natural constitution, equally ready both for susception and emission. That bleareduess is infectious, and that a sound eye receives the morbific effluvia from the bleared eyes of another, is plainly made out by experience, and affirmed unanimously by the leading men of our profession.

In like manner that bewitching, which is said to be performed by a cast of the eye, seems to be brought about by a bright emanation from the eyes of the enchanter, which insinuates itself into the eyes of another, and being somewhat allied to it, and thus infects them.

This is not a place for enquiring further into the eyes, so I shall only stay to quote a noble passage out of Plato. He brings in Socrates, unfolding the meaning of that famous inscription in the entry of the Delphic Temple: "Have you not observed," says Socrates to Alcibiades, "that the face of a man looking upon the eye of another is in the most prominent part, or the pupil, of that other's eye, exhibited as in a glass? Thus the eye at last gets a view of itself when it on all hands looks on another eye, but is particularly careful to observe that which is best in the eye, and that by which itself sees: an eye, therefore, to perceive its own picture must look upon another eye."

To return to our subject.—The cleansers of jakes being of necessary use to all cities, it is but reasonable that the art of physic should provide some relief for them, especially considering that the civil law was so favorable to them as to prohibit the offering of the least injury to them, even though they should penetrate into another man's house. I have advised them to put transparent bladders over their faces, as those do who polish red lead, or to spend less time at once in cleansing the jakes; or, if their eyes are weak, to leave that business, and apply themselves to some other trade, for fear of being obliged, for the sake of sordid lucre, to lose their eyes, and so beg their bread. Experience itself has taught them, and indeed it is agreeable to reason, that keeping within a dark room is very proper, as well as washing the eyes with warm water, which mitigates the heat of the eyes and lessens the pain, which, like a thorn pushed in, occasions the contraction of the nervous parts, and consequently an inflammation. If the eyes are very red, and there is ground to apprehend a true inflammation, I order bleeding, and as soon as the heat of the eyes is a little abated, I advise them to wash them with Muscadine wine, which in this case is an excellent remedy. For it invites, in a manner, the animal spirits to come from the brain and the optic nerve to return to the eyes, from whence they had been driven by the sordid and penetrating damps.

The *Acta Haffniensia* relates the case of a woman, who, by working hard in making candles for the market, was seized with a violent pain in the head, with a giddiness, a redness in the eyes, and a difficulty of respiration.

Nurses are subject to weakness of the eyes, headaches, a giddiness in the head, a difficulty of breathing, and the fluor albus, especially if they suckle for several years.

"Of the Diseases of Bakers and Millers." The particles of the flour or meal, which adhere to the eyes, pinch them very much, and often occasion a bleareredness.

Millers and grinders come into the same list with the bakers; for the particles of fine flour fly about and fill the whole mill, so that in spite of their teeth, their mouth, nostrils, eyes, ears, and indeed the whole body is covered with meal.

The ancients had not such machines for grinding corn as we have, by the help of waterfalls which turn great wheels about. They used to grind their corn in pistrina, which are now used for bruising and taking the husks off grain. Their wheels were turned not only with cattle, but with men, and slaves, and women. And from thence rose the name of handmills, because they turned them round with all their force. Criminals were commonly condemned to this work at the pistrinum: and we see in Plautus, there was nothing more frequent, nor so ominous to slaves, as the word pistrinum. L. Apuleius says: "He was made an ass, tyed to a mill with his face covered, and forced to tread over his own footsteps." We read in sacred writ, that Samson had his eyes put out by the Philistines, to qualify him for the turning of a mill (which was probably a hand-mill), for they used to put out the eyes of such as were doomed to this service, to prevent their being giddy.

"Of the Diseases of Sifters and Meters of Corn." The throat, the lungs, and the eyes sustain no small damage by the powder and rotten dust, for it stuffs and dries up the throat; it lines the pulmonary vessels with a dusty matter which causes a dry and obstinate cough; and it makes the eyes red and watery. The workmen employed in those services used to cover their mouths and nostrils with handkerchiefs, to keep out the dust, and to wash their throats and eyes often with cold water; but all this caution is not sufficient to indemnify them.

The Jews, and particularly the vulgar sort, are accustomed to sedentary and standing trades. Sewing, and fitting up old clothes is an employment they always follow, but their women, whether maids or married persons, gain their livelihood by their needle more than any other women whatsoever. This employment strains the eyes very much; for the women sit at it, not only all day, but even late at night by a very faint light, such as funeral lamps generally cast; and thus they not only undergo all the disadvantages of a sedentary life, but in process of time contract such a weakness in their sight, that, by the time they are forty years of age, they are short-sighted. Add to this, that in most cities the Jews live in narrow lanes, and their women have a custom of standing at the windows in all seasons of the year to take advantage of the light; by which means it comes to pass, that they suffer various disorders in the head, such as headaches, pains of the ears and teeth, a dull heaviness, a hoarseness and bleeredness of the eyes.

I would advise the women, especially those who follow the sewing trade so close, to spare some hours now and then for the sake of their healths; and to ease both their hands and their eyes, for fear the loss of their eyes should afterwards oblige them to an idle and a miserable life.

"Of the Diseases of those who work on Minute things which strain the Eyes." There are some tradesmen employed in the finer and smaller sort of workmanship, such as goldsmiths, watchmakers, painters, I mean those who paint upon jewels, and writers, such as he who wrote Homer's Iliads in the compass of a nut-shell, as Tully informs us.

The misfortune entailed upon those men from their business, besides the inconveniences of a sedentary life, is that common disease of the eyes called myopia, in which the objects are not seen unless they be placed near the eye; and accordingly we see most of these tradesmen use spectacles at work. Wedelius makes mention of this sort of tradesman in a particular manner, and says, they are weak-sighted, because it is usual for the parts which are most exercised to be most weakened. But we may draw a better reason for this weakness of the eyes from the principles of the optics.

I was always of the opinion, that nothing can illustrate the manner of vision, but a dark room, in which the images of external things are represented upon a white linnen cloath; which thought we owe first to Platerus, and then to Plempius in his Ophthalmographia. For if we place a convex glass in the hole of a dark room, the nearer the object approaches to the hole, the further must the cloath be removed from the aperture, to make a distinct representation of the object; and, on the other hand, the further the visible object is removed, the nearer must the cloath be brought to the hole, otherwise, the representation will become confused; for the distinct images of things are drawn, as it were, with a pencil only in the point where the rays join. From hence it appears, that the eye, which is of a finer and more admirable structure, cannot distinctly see objects at a distance, and near at hand, unless it be moveable, and apt to change its figure; so that, either the net-like coat, or the crystalline humor, may be easily moved. Common experience teaches us, that, when we view objects at a distance, and do not perceive them clearly. because the rays, entering the eye almost parallel, meet too soon behind the pupilla, we can by straitening and contracting the eyes, by the means of the muscles and eyelids, so alter the figure of the eyes as to have a clear and distinct perception of the objects, which otherwise we saw but confusedly.

Now, these who work all day long upon very fine and small work, cannot have a distinct view of the minute objects before them, without keeping their eyes very steady and intent, and fixed with a tonical sort of motion, or a motion always directed to one point; and consequently, though their eyes are naturally movable, that being a necessary quality for perceiving objects at a distance, as well as near at hand, yet, by keeping the eye constantly in this one position, they contract such a habit that the retina being inured and accustomed to one form and figure, persists in it, and cannot be moved at pleasure for the perception of remoter objects. And it is for this reason that such tradesmen are almost all of them troubled with myopia.

Add to this, that, while the eyes are kept immovable, and perpetually fixed upon one point and the humors grow thick and lose their transparency along with their fluidity, which gradually make way for a weakness of the sight; so that, though such tradesmen may have nimble and clear-sighted eyes, they may become short-sighted in process of time.

So great is the calamity entailed upon this sort of work, and the finest pieces of workmanship, such as clocks and watches, are so apt to produce this weakness of the eyes, that many of the workmen are almost blind before they arrive at old age. I know a woman in this city who had a peculiar way of stringing pearl, and that so artificially as to cover their blemishes, if there were any, and by this means she got a great deal of money. But when she came to be forty years of age, finding no manner of relief from spectacles, she was forced to leave off the business. I remember, likewise, to have heard several printers complain that they have given a considerable shock to their eyesight by composing small types.

In earnest, I do not see how we can afford any relief to the workmen we now treat of; for it is not easy to persuade them to leave a beneficial and lucrative trade; and physic is unprovided with any remedy which can restore the primitive strength and mobility of the eyes, after the disorder is become inveterate; for neither purging, nor bleeding, nor the other medicinal means can take place in this case in regard the patients are otherwise well and brisk, and their spirits being neither clouded nor incrassated, it would be improper to punish an innocent and sound head with the commotions of medicines.

However, I would advise such workmen not only to use spectacles, but to intermit from their work now and then, and refresh their eyes with diversity of objects. For we cannot imagine how much the mobility of the membranes of the eyes and the native humours is kept up by viewing different objects, some near at hand, some remote, some directly, others obliquely, and, in fine, all manner of ways; for by this means the natural disposition of the eye is preserved, so that the ball is sometimes furled or contracted, and sometimes dilated; and the chrystalline humour approaches more or less to the pupilla, according to the remoteness or nearness of the object requires. Without this diversity of action, the eyes undergo the same fate as the other parts, which, by being long detained in one position, grow stiff and unfit for motion. Of this we have a manifest instance in those who, upon coming out of dark prisons where they have been long kept, are forced to accustom their eyes gradually to the light, because the pupilla or ball of the eye having been long dilated and its elastic spring weakened, it forgets, in like manner, how to contract itself as it used to do.

"Of the Diseases of Husbandmen." But as Husbandmen follow various sorts of work, according to the diversity of the country, and the seasons of the year, they used to be troubled in winter and the beginning of the spring, with the diseases of the breast, defluxions upon the eyes, and quinsys.

I have made one remark, which is curious, in our farmers' families, especially in their children; which is, that these children, being for the most part under ten years of age, are seized about the vernal equinox, with such a dimness in their sight, that they run up and down all day long as if they were blind; but, upon the approach of night they see very well. Now this disorder goes off of itself, without the assistance of any remedy; for about the middle of April, they become as well as ever. Upon such occasions, I have often taken a narrow view of these children's eyes, and found the pupilla, or ball, much dilated, which disorder the physicians call by the name of Mydriasis, though authors differ in their thoughts of the cause of it, as you may see in Sennertus, Riverius, and Platerus.

Gorreaus says, this distemper is not much different from the resolution of the pupilla; and indeed, it seemed to me, that the rays of the sun in March, might make some colliquation in the brain and optic nerves, by which the means the tone and the spring of the coat, called Uvea, may be so resolved, that it becomes flaccid.

These children live all the winter in very hot and moist huts; and when the winter is broke, that is, about the vernal equinox, they peep out of their dungeons, and expose their bare heads to the sunbeams, upon which a fusion and colliquation of the humours may readily ensue; and from thence proceeds the dilatation of the eyeball, and a weakness of sight, by reason of the admission of an excessive quantity of light; but, towards the end of April, the sunbeams being more effectual, discuss the humours which had just fallen upon the coat; and, the pupil being restored to its natural tension and lightness, the eye sight is recovered without the intervention of remedies.

"Of the Diseases of Learned Men." They likewise contract a weakness of the sight by degrees, for they cannot read and write with an intent posture of the eyes without injuring the sight, especially if they write small, as quick-witted men commonly do. Aristotle has a curious conjecture enough, if it were but true, upon the question why pur-blind persons usually write small letters. "It is strange," says he, "that those who are dim-sighted should do that which the sharpest-sighted ought to do." For this practice of pur-blind persons he brings several reasons, and so does Plempius, who says, "He has sometimes doubted whether it was only a sort of affection in such people as he thought quick-sighted." But I know a great many such who write their letters large enough, though it is not to be doubted but that those who accustom themselves to write small and fine grow thereupon shorter-sighted, and by degrees contract a myopia. For by that means the eye is accustomed to see only such objects as approach near to it, and by virtue of that custom the retina is confirmed, and hardened in a remoter situation from the pupilla, and so the eye is robbed of the mobility which nature gave it.

Sometimes those who read and write much are troubled with the disorder which is opposite to a myopia, so that in process of time they cannot see unless the object be held at a distance from them. And this is familiar to old men, for since they write and read with their head and body bended forward, the crystalline humour readily falls forward towards the pupilla, and stops it up so as to cause a blindness. Hence, Platerus gives this as the reason why horses and other brutes are under disorders of the eyes more frequently than men, because as they go with their faces bowed to the ground the humours of the eyes are gradually carried forward, and there they settle.

"Of the Diseases of Printers." The compositors also, by having their eye perpetually fixed on the black types, contract a weakness of sight, and become subject to cataracts and other disorders of the eye. I know two brothers, printers, with eyes naturally large and prominent, who were forced to quit the business, lest they should become blind. I also remember, that by sitting some hours with a printer in order to correct some work of my own, when I went out of the printing house, I perceived the types, as it were fluctuating before my eyes, and even in the night-time had the images of them represented to my imagination, because I had viewed them so long and with so much attention. By having the eyes continually fixed then upon the black types, whether in composing or distributing letter, the tone of the membranes and fibres of the eye, and especially of the pupil, is greatly weakened, so that it is no wonder printers should be subject to disorders of the eyes.

The compositors themselves inform us that when they come abroad at night, after working the whole day, the images of the types seem to be imprinted on their imaginations, and there remain some hours, till they are effaced by the representations of other objects.

Compositors ought also to use spectacles in order to preserve the tone of the eye, to turn their sight frequently off the types, and gently rub their eyes, in order to rouse their lanquid spirits, and to wash them with water of eye-bright and others of a like nature.

"Of the Diseases of Confectioners." The conditions induce upon confectioners violent disorders of the brain, breast, and eyes, for the head is afflicted with a violent pain, the eyes are often inflamed and pricked as it were with darts, by the exhalations of the fire, and respiration is injured by the acrid particles contained in the inspired air. Confectioners ought therefore, if possible, to work at their business in an open place, for the dissipation of the corrupted air, and so spend some hours a day in taking the fresh air, after washing their faces with water, and their fauces with roses.

"On the Diseases of Braisiers." Persons of this profession inform me that these noxious exhalations produce no disorders of the eyes, which is agreeable to the assertion of Macrobius, who tells us: Lippitudes and inflammations of the eyes are cured by working in Brass Mines; for which reason 'tis customary with some persons to prepare collyriums with brass.

"Of the Diseases of Carpenters, Joiners and others." They must also have their eyes constantly and attentively fixed on their work, by which means they are considerably injured, since by the circumgyration of the wood, their spirits and humours contract a kind of vertiginous motion.

The best advice I can give to tradesmen of this kind, in order to prevent diseases, is, not to overwork themselves, and by that means bring on disorders which may for a long time incapacitate them for their business.

They are also to preserve and defend their sight, by frequent intermissions from labor; and if their eyes should be seized with a pain or redness, they are to be washed with temperate substances, such as barley water, water of violets, and women's milk.

"Of the Diseases of Cutlers and Razor Makers." By continually and attentively fixing their eyes upon the grindstone which is turned round with excessive velocity (these workers) have the tone of their eyes impaired, and in process of time their sight rendered dull. Some of them also, especially those who have weak heads, are, after working a whole day, not only subject to vertiginous disorders, but also imagine that they see the stone turning before their eyes. 'Tis probable, that by this external and occasional cause the humours of the eye, especially the aqueous, which is naturally movable, and the animal spirits are put into a gyratory motion, by which means the natural oeconomy of the eye is perverted. I knew a skilful razor maker, who, after working for a whole day, was generally afflicted with violent inflammations and redness of the eyes, nor could he charge his misfortune upon any other cause or circumstances than his business.—(J. Gray Clegg.)

Ramous. Ramose. Having branches; ramified.

Rampezzetto. An Italian who first (in the sixteenth century) invented carved letters (in wood) for the blind. See **Alphabets for the blind.**

Rampoldi's sign. As pointed out by Casey Wood (*Medicine,* Vol. II, No. 1, p. 34, Jan., 1896) Rampoldi (*Annali di Ottalm.,* Vol. XIV, No. 4) was probably the first to draw attention to the unilateral dilation and sluggishness of the affected pupil as an early sign of bronchial gland tuberculosis. T. L. Teuchter (*Journ. Am. Med. Assoc.,* Feb. 24, 1912), reports four cases of tuberculosis of the apex of the lung in which he noticed that one pupil was larger than the other and reacted more sluggishly to light. It is probable, says the author, that these pupillary symptoms were caused by an involvement of the bronchial glands which caused them to swell and press upon the sympathetic nerve on the affected side. See, also, **Pupil** captions.

Ramsden's eye-piece. Ramsden's ocular. This device consists of two plano-convex lenses, of equal focal lengths, whose convex surfaces inwardly face each other and are separated by a distance equal to two-thirds of the numerical value of the focal length of either lens. See also **Eye-piece,** p. 5031, Vol. VII of this *Encyclopedia.*—(C. F. P.)

Ramus ophthalmicus (quinti). (L.) Ophthalmic nerve.

Randgeschür. (G.) Marginal ulcer.

Range-finder. An appliance for determining the distance of an object under observation. They are most useful in military operations for determining the range or distance of an enemy in the field, one of the best-known being the Watkin range-finder, which was introduced into the British army in 1882. It is contained in a rectangular box about 6¾ x 2¾ x 1½ in., and is based on the principle of the sextant. Its use may be briefly described as follows: Let O be the object to be observed from A; a base line AB of known length, from 60 to 120 yards, is taken at right angles to AO. When the instrument at B is set to observe O the angle at ABO is obtained, and the distance OA can then be calculated or read off from the instrument. For field artillery purposes it is essential that range-finders be easily transportable. Of these one of the best is the Weldon, which consists of three prisms of different angle, fixed one above the other in such a way that when in use the prisms can be brought into position, and any of them used without having to take the eye off the object observed. For sea-coast artillery range and position finders are usually mounted permanently on solid foundations. In this case it is important to have a base line which may be either horizontal or vertical. In the former case two instruments are used, one at each end, and the azimuths read off are sent by some means to the plotting room. Here the position of the target is determined mechanically, and then sent to the gun. When a vertical base is used, only one instrument is necessary, a depression position finder. The base line for good results in this case should not be less than 80 ft. A good length for a horizontal base line is 2,000 ft., which must be accurately measured. See publications of the Ordnance Department, United States army; and *Drill Regulations,* Artillery Corps, United States Army.—*(Standard Encyclopedia.)*

Range of accommodation. The alteration in the refractive state of the eye produced by accommodation. It is the difference in diopters between the refraction by the eye adjusted for its far-point and that when adjusted for its near-point. See **Amplitude of accommodation,** p. 329, Vol. I of this *Encyclopedia;* also **Refraction and accommodation of the eye.**

In calculating the normal range of accommodation at various ages, Duane and Thomas' (*Oph. Year-Book,* p. 90, 1909) determinations differ somewhat from those of Donders. The accommodation in childhood and youth was lower—rarely above 14 D. between 8 and 13 years. The range does not seem to diminish much between 10 and 15 years; the maximum may even occur at 16 or 18, though this requires further investigation. The accommodation does not decrease steadily at all ages, but appears to remain about stationary for some years and then diminish rapidly; from 25 to 30, and again from 35 to 40, are periods of special stasis, but further observation is necessary. An abrupt plunge seems to occur at 40, and to continue until 51, after which age the accommodation remains nearly constant, diminishing not more than 0.50 in ten years. Certain peculiarities in the behavior of the function were found in individual cases, and unequal power in the two eyes was not uncommon.

Range of accommodation, Binocular. See **Accommodation, Binocular range of,** p. 50, Vol. I of this *Encyclopedia.*

Range of vision. In general, all that can be distinctly seen at any distance between the near and far points of the observing eye.

Ranney, Ambrose Loomis. A celebrated anatomist and neurologist who, late in life, became an ophthalmologist, and who was one of the first physicians in America to direct the profession's attention to eye-strain as a cause of general diseases. Born at Hardwick, Mass., June 10, 1848, one of the thirteen sons of Lafayette and Adeline Eliza Loomis Ranney, he received the degrees of Bachelor and Master of Arts at Dartmouth College, and then proceeded to study medicine under his uncle, Alfred L. Loomis, in New York City. His medical degree was received from the University of the City of New York in 1870. It is worth noting that six of Dr. Ranney's twelve brothers were doctors, that his father, Lafayette Ranney, was a doctor, while two of the father's brothers (as well as the mother's brother, Dr. Loomis) were doctors also—Evander and James W. Ranney.

The most of Dr. A. L. Ranney's life was given to general practice in the city of New York. During all these years, however, he devoted especial attention to anatomy and neurology. Late in his career he became an ophthalmologist, and, as such, was remarkably successful. He was also widely known as a medical expert, and in this capacity served the Erie R. R. for fifteen years, the New York and Harlem River R. R. for twenty years, the New York, New Haven and Hudson River R. R. for thirty-five, and the New York Central for forty.

As a medical expert, Dr. Ranney was especially known for his calmness and self-assurance on the stand. He was also often very witty, so that counsel was often inclined to dread his retorts. Chief Justice van Brunt is, indeed, declared to have observed that "Any lawyer who attempts to cross-examine Dr. Ranney is a fool."

Dr. Ranney was for years professor of nervous and mental diseases in the University of Vermont, and adjunct professor of anatomy in the University of the City of New York. He was, for a time, president of the New York Academy of Medicine.

His chief works were: *"Essentials of Anatomy"* (1880); *"Practical Medical Anatomy"* (1882); *"A Treatise on Surgical Diagnosis"* (1884); *"The Applied Anatomy of the Nervous System"* (his masterpiece, 1888).

Dr. Ranney was a genial, companionable man, a skilful billiardist, a sportsman, a yachtsman, and "an owner and driver of fast horses." He married, in 1876, Miss Marie Celle, of New York City, by whom he had two children, A. Elliott and Marie Bryan. He died suddenly, from heart disease, on Friday, Dec. 1, 1905, in the down town office of a friend.—(T. H. S.)

Raphé palpebralis lateralis. (L.) A name for the external palpebral (tarsal) ligament.

Raphiankistron. An instrument invented by Schlagintweit for the formation of an artificial pupil. It never came into general use.

Rapidity of a lens. A term used in photography to indicate the efficacy of a lens in producing changes in a photosensitive plate.

Rashid ad-din. An uncle of the much more famous Arabian ophthalmologist, Usaibia. He was one of the overseers of "The Ophthalmic Hospital" at Damascus.—(T. H. S.)

Rathlauw, Johann Peter. A celebrated Dutch obstetrician, surgeon and ophthalmologist. The dates of his life and death are not precisely known, but he flourished in the middle third of the 18th century. He studied in Paris and London under St. Yves and Ferrein, and shortly afterward settled in Amsterdam. [He was for a time excluded from practising as a physician (but not, it would seem, as an obstetrician) because he had purchased and kept to himself the secret of the obstetrical forceps.] By the aid of Thomas Sewencke, professor of anatomy and surgery at Amsterdam, he finally secured admission to the College of Physicians. In addition to works of a general medical character, he wrote *"Verhandeling van de Cataracta, derzelve Oorzaken, Kentekenen en Gevolgen, en inzonderheit de Manier der Operatie"* (Amsterdam, 1752).—(T. H. S.)

Rational horizon. The astronomical horizon.

Ratio of conjugate slope-angles. See **Angular magnification,** p. 477, Vol. I of this *Encyclopedia.*

Rattle-grass. According to Pliny the elder, an ophthalmic remedy. See **Cock's comb,** p. 2312, Vol. IV of this *Encyclopedia.*

Rattlesnake venom. Although it is well known that snake poison occasionally produces amblyopia (see **Toxic amblyopia**) yet there are few instances reported of the oculotoxic effects of the virus of *Crotalus.* Of these Wynter (*Ophthalmic Year-Book,* p. 414, 1914) reports a case of non-fatal rattlesnake bite with ocular symptoms which included diplopia, dimness of vision, swelling and drooping of the lids, and slight inequality of the pupils. See, also, **Crotalus horridus,** p. 3571, Vol. V of this *Encyclopedia.*

Rau, Wilhelm. A well known German pediatrist and oto-ophthalmologist. Born at Schlitz, Germany, in 1804, son of the physician, Gottlieb Martin Wilhelm Ludwig Rau, he studied at Erlangen, Tübingen, Giessen, and Heidelberg, receiving his medical degree at Giessen in 1826. He was for a time Privatdocent in ophthalmology at Giessen. Later he was made professor extraordinarius in pediatry and ophthalmology at Bern. The date of his death is not known.

Rau's ophthalmologic writings are as follows:

1. *Ueber die Erkenntniss, Entstehung und Heilung der Staphylome des Menschlichen Auges.* (Heidelb. and Leipz., 828.)
2. *Die Krankheiten und Bildungsfehler der Regenbogenhaut.* (2 Abth., Bern, 1844.)
3. *Ueber die Sinnesorgane Ueberhaupt und de Pflege des Auges Insbesondere.* (Bern, 1858; 2d ed., 1859.)—(T. H. S.)

Rauchapfel. (G.) Datura stramonium.

Raupe. (G.) Caterpillar.

Rava, Jacob. An Italian surgeon, who devoted especial attention to hygiene and ophthalmology, and who revived the ancient operation of coloring opacities of the cornea. Born at Milan, Oct. 10, 1837, he received his medical degree in 1859, and fought for a time under Garibaldi. Settling in Pavia he became assistant to the eye clinic in that place. In 1864 he removed to Sassaria, there to accept the chair of ophthalmology, and, in 1878, the full professorship. He died in 1911.—(T. H. S.)

Ray. A line of light, or some other form of radiation; scientifically, the normal to the wave surface.

Ray cataract. A name given to a form of stellate cataract by Cridland (*Ophthalmoscope,* p. 126, Mar., 1915) who reported an example in a puddler. The conjunctivæ were chronically inflamed. The right lens showed a central nuclear haze with a small, dense opacity thinner centrally, situated in the extreme posterior layers of the cortex. A few radial striæ were present, although the peripheral portion of the lens was comparatively clear. The left lens showed similar changes.

These lenticular opacities are produced in glassblowers, puddlers, electric welders, *et al.,* by exposure of their eyes to intense heat and dazzling light, or to both these injurious agents. See **Puddlers, Eye diseases of.**

Ray-filter. See **Color-screen**, p. 2419, Vol IV of this *Encyclopedia.*

Ray, James Morrison. A well known ophthalmologist of Louisville, Ky. He was born Aug. 10, 1860, at Bloomfield, Nelson Co., Ky., son of Isaac M. and Ruth (Bodine) Ray, and nephew of the celebrated Dr. James M. Bodine. He received the medical degree at the University of Louisville in 1882, and, after a brief period of general practice, went to New York, where he studied the eye, ear, nose and throat in the Manhattan Eye and Ear Hospital. While in this institution he was assistant to the famous Dr. Cornelius Rea Agnew.

Returning to Louisville in 1885, Dr. Ray settled in that city as ophthalmologist and oto-laryngologist, and was immediately afterward appointed a clinical assistant in ophthalmology, otology, and laryngology in the Medical Department of the University of Louisville. He afterwards studied the eye, ear, nose and throat in Paris, London, and Vienna, and, returning to Louisville, was awarded the full professorship of ophthalmology in his alma mater. When the various Louisville schools merged with the Medical Department of the University, Dr. Ray was elected Chairman of the Medical Faculty, a position which he held till his death. He was ophthalmic surgeon to the Louisville City and to the SS. Mary and Elizabeth Hospitals, a Fellow of the American Ophthalmological Society, a delegate to the International Medical Congress at London in 1913, and a Fellow of the American College of Surgeons. He was a Baptist.

Dr. Ray never married. He died in Louisville, Oct. 11, 1918, of chronic Bright's disease, survived by only two near relatives, sisters —Mrs. Sam Fulton, of Florida, and Mrs. Kate Wilson, of Louisville.

Dr. Ray was a large, stout man, of a fair complexion, and with gray eyes and brown hair. He wore, as a rule, a mustache. Concerning his mental characteristics a friend has written as follows: "It was said of him that his assiduity to and love for his profession served as an inspiration to the younger generation of physicians in Louisville. He had gruffness of manner which, however, was only a cloak concealing a generosity of heart of unusual character. This, it was said, was the outstanding feature of his unique personality. Even to those he loved most, this characteristic was most apparent, and it was something which those who met him casually seldom failed to remark. This trait of gruffness concealing over-generosity, as it was known, was something to which hundreds of persons he had given the best of his skill in the alleviation of disease and suffering might testify. Many of these never received a bill from him. Others, it is said, were made everlastingly grateful by a modest charge from an unusually able specialist."—(T. H. S.)

Raynaud's disease, Eye signs of. This is a juvenile or young adult disease marked by attacks of cold or other symptoms accompanied by emotional excitement; in severer cases by local capillary congestion and livid swellings which in some instances terminate in gangrene.

Rayner Batten (*Oph. Review,* p. 225, July, 1910) reports a case associated with retinal hemorrhage, and other changes in the retinal vessels. A female patient came for treatment of failure of sight in the left eye, of three or four weeks' standing. In April, 1910, she had sudden failure of vision, from which she partially recovered, followed by another attack in a month's time, accompanied by sudden pain in the eye. With the ophthalmoscope there were seen several hemorrhages in the fundus, and the upper temporal artery appeared to terminate suddenly where crossed by the corresponding vein, and became lost in an area of retinal disturbance. Raynaud's disease had existed for eleven years, and two toes were gangrenous.

E. E. Blaauw (*Sammlung Zwangloser Abhandlungen an dem Gebiete der Augenheilkunde,* Vol. IX, 3, 1913) was consulted by a patient suffering from Raynaud's disease, who complained of paroxysmal pain in the eyes associated with definite temporary deterioration of vision.

From a study of this case and of the literature the author believes that attacks of temporary loss of vision are not uncommon in association with Raynaud's disease. In the majority of cases in which the fundus was examined, neither during an attack nor between the attacks could any change be seen in the retinal vessels. In ten cases, however, changes in the fundus vessels have been described; one of these cases was reported by Raynaud himself. But in none of these was an examination made by an experienced oculist, and in some of them the changes described may have been due to arteriosclerosis. This was most probably the condition of affairs in the case described by Raynaud. There is, therefore, no satisfactory evidence that Raynaud's disease can cause a spasm of the retinal vessels, and the fact that in the reports of many of the cases it is specially stated that the retinal vessels were normal, is evidence in the other direction.

It is possible that the temporary loss of vision does not depend on the retinal vessels at all, but on interference with the circulation through the vessels of the uveal tract.

Ray of minimum deviation. See **Angle of deviation,** p. 474, Vol. I of this *Encyclopedia.*

Rayometer. A kind of actinometer. See p. 84, Vol. I of this *Encyclopedia.*

Rayon de lumière. (F.) Ray of light.

Rays, Actinic. A light-ray which produces in particular chemical changes. They are found mostly in the violet and ultra-violet portions of the spectrum. See p. 83, Vol. I of this *Encyclopedia.*

Rays, Alpha. Those radio-active emanations that have the lowest velocity and penetrating power. They consist of positively charged particles having great velocities, but small masses. See **Radium.**

Rays, Becquerel. These rays have the penetrating properties of the Röntgen rays, but are capable of being polarized, reflected, and refracted. See **Radium.**

Rays, Beta. Those radio-active emanations that have a moderate velocity and penetrating power. They are charged with negative electricity and are deflected by a magnet. See **Radium.**

Rays, Blondlot. See **Rays, N.**

Rays, Delta. Rays of high penetrating power given off from radium and other radio-active substances. They are waves of motion and not electrically charged particles like the *alpha* and *beta* rays. See **Radium.**

Rays, Finsen. See **Finsen lamp,** p. 5203, Vol. VII of this *Encyclopedia.*

Rays, Gamma. Those radio-active emanations that have the highest velocity and penetrating power. See **Radium.**

Rays, Goldstein's. S-RAYS. Rays formed when x-rays pass through some transparent medium.

Rays, Hard. X-rays of short wave length, but which penetrate the tissues.

Rays, Hertzian. Electro-magnetic waves in the ether similar to a light-wave, but having a greater wave-length.

Rays, Lenard. Cathode rays after they have issued from a Crookes tube through a window of platinum foil.

Rays, Minin. Rays generated by passing incandescent light through dark-blue glass.

Rays, N. Non-luminous rays having a wave-length below that of heat and light and above that of electricity. These rays are emitted along with light-rays from ordinary flame, and are also given off by certain bodies, as glass, wood and rubber, when forcibly compressed and twisted. The rays have the power of passing through platinum, aluminum, tin-foil, glass, gold-leaf, and saline water, but they are arrested by pure water and by lead. They also have the property of increasing the luminosity of light and of producing luminosity in fluorescent and phosphorescent bodies. It has been stated that the rays are emitted by living nerve and muscle. Called also Blondlot rays. A variety of *n′*-rays; differs from *n*-minus rays in diminishing the luminosity of light and of faintly luminous surfaces.

Rays, Nieuenglowski's. Luminous rays given out by substances which have been exposed to the sun.

Rays, Röntgen. (After W. K. Röntgen, of Würzburg), a species of energy having the property of penetrating substances that are ordinarily opaque and of affecting an ordinary photographic plate.

It is generated by an electric current passed through a Ruhmkorff coil and thence to a highly exhausted vacuum tube (Crookes' tube, Geissler's tube), and is used in taking photographs (skiagrams or shadowgrams) through the flesh and through various opaque objects. Röntgen rays are also employed in the treatment of lupus, skin-cancer, and other affections. See, also, **X-rays**; as well as **Radium.** See also **Fluoroscope**; and **Localization,** p. 7503, Vol. X of this *Encyclopedia.*

Rays, Sagnac. Secondary *beta* rays formed when *gamma* rays are reflected from a metal surface.

R. E. Abbreviation for *radium emanation;* also for *right eye.*

Reaction, Abderhalden's. A serum reaction based upon the fact that when a foreign protein gets into the blood the body reacts by elaborating a ferment which causes disintegration of the protein. Such a ferment is called a protective ferment and is specific for the particular protein which caused its formation. This reaction was first applied to the diagnosis of pregnancy on the principle that in the blood of pregnant women there is present a proteolytic ferment which will cause cleavage of placental albumin and placental peptone. The same principle is applied to the diagnosis of cancer because the blood of cancer patients contains a ferment which digests coagulated cancer protein. Similarly, in dementia præcox, the brain becomes degenerated and furnishes to the blood substances which excite the formation of a ferment capable of decomposing proteins of human brain. This is the Abderhalden-Fauser reaction. The same principle has also been applied to the diagnosis of syphilis, tuberculosis, and the acute infections. (Dorland.) See, also, the introduction to **Keratoconus,** p. 6825, Vol. IX of this *Encyclopedia.*

Gebb (*Bericht der Ophthal. Gesellsch.,* p. 34, 1913) has employed Abderhalden's reaction to determine whether the serum of patients with cataractous lenses differs biologically from the serum of individuals with clear lenses. Using the dialysis method, he obtained in every instance a negative result, but he found the optical reaction much more delicate, and the ten cases of cataract examined all showed the presence of the characteristic ferment by rotation of the plane of polarization.

Gebb points out that the serum of old people often gives a reaction with ninhydrin if more than one cubic centimetre of the serum is employed. To avoid this source of error, not more than that amount should be used.

Von Hippel (Harrison Butler's review in the *Ophthalmoscope,*

p. 165, Mar. 1914 of the article in the *Bericht der Ophthal. Gesellsch.*, p. 26, 1913) has made further observations: He first sought to decide whether the blood of persons affected with sympathetic ophthalmia gave the biological reaction to uveal tissue. Eight cases were examined. Three gave a positive reaction, but five failed to do so. The uvea of oxen was employed as a test, and, as far as possible, all pigment was removed by filtration. The deduction is that in some cases of sympathetic disease a pathological cell substance is present in the uveal tissue, which causes foreign proteid to appear in the blood, and starts a biological reaction. Controls were made in two cases with vitreous, lens substance, liver, placenta, and other substances, always with a negative result. The reaction was obtained only when uveal tissue was employed. Seven cases of perforating injuries were tested, and four of them reacted positively.

v. Hippel concludes that the reaction is of no value in diagnosis, especially early diagnosis; that it does not help the prognosis; and that it throws no light upon the nature of the disease. The reaction is not specific for sympathetic ophthalmia.

Some experiments were also made in cases of lamellar cataract with tetany, and with corneal substance trephined, and of eyes suffering from interstitial keratitis.

Reaction, Austrian's. An ophthalmic reaction for typhoid fever by the use of an antigen prepared from a mixed culture of a large number of different strains of typhoid bacilli.

Reaction, Calmette's. See **Calmette's ophthalmic reaction**, p. 1361, Vol. II of this *Encyclopedia*.

Reaction, Chantemesse's. The ophthalmic reaction for typhoid fever, following instillation into the eye of typhoid toxins. The reaction is much more severe than in normal individuals or in those affected by another disease.

Reaction, Consensual. A reaction that takes place independently of the will. See p. 3186, Vol. V of this *Encyclopedia*.

Reaction, Cutaneous. Local reaction of the skin following inoculation with tuberculosis toxins. It is more marked in tuberculous subjects than in normal ones. The term is usually applied to the von Pirquet test (q. v.). See p. 10228, Vol. XII of this *Encyclopedia*.

Reaction, Epiphanin. A reaction for the determination of antibodies in the blood-serum, especially in the serodiagnosis of syphilis. The technic depends on a change of reaction to phenolphthalein in a neutralized solution. A mixture of the suspected solution and of an extract from a syphilitic organ are made as follows: 0.1 c.c. of a 10 per cent. solution of the serum in physiologic salt solution is mixed with 0.1 c.c. of an alcoholic extract of a syphilitic fetal liver. To this is slowly added 1 c.c. of decinormal sulphuric acid and 1 c.c. of an exactly equivalent solution of barium hydroxid. On the addition of a drop of phenolphthalein solution the fluid turns red if the serum is from a syphilitic, while there is no change in tint with the serum of a non-syphilitic person. See, also, p. 4492, Vol. VI of this *Encyclopedia.*

Reaction, Fornet's. A test for syphilis. The serum of the patient is treated with the serum taken from a paretic. If syphilis is present, a flocculent ring will appear at the line of contact of the two serums.

Reaction, Hemiopic pupillary. HEMIKINESIA. WERNICKE'S TEST. In certain cases of hemianopsia the stimulus of light thrown upon one side of the retina causes the iris to contract, while light thrown on the other side arouses no response. See p. 4621, Vol. VI of this *Encyclopedia.*

Reaction, Herxheimer's. An inflammatory reaction produced in syphilitic tissues following the ingestion of salvarsan, mercury, or other specific treatment, supposed to indicate failure of the drug to cure.

Reaction, Loewi's. Dilatation of the pupil following the instillation into the eyes of a solution of adrenalin.

Reaction, Moro's. An eruption of pale or red papules on a cutaneous area after the application of an ointment of 5 c. c. of old tuberculin and 5 gm. of anhydrous wool-fat. See **Moro's reaction,** p. 7867, Vol. X of this *Encyclopedia.*

Reaction, Noguchi's luetin. A cutaneous reaction for syphilis. A drop of luetin is injected into the skin of the arm. No reaction occurs in a non-syphilitic person, but in one affected with syphilis there forms, in from six to twenty-four hours, a distinct papule surrounded by a bluish-red halo. See **Luetin,** p. 7543, Vol. X of this *Encyclopedia.*

Reaction, Ophthalmic. Local reaction of the conjunctiva following instillation into the eye of toxins of tuberculosis. The reaction is much more severe in persons affected with these diseases than in the healthy or those affected with some other disease. See **Calmette's ophthalmo-reaction.**

Reaction, Pain. Dilatation of the pupil following a painful sensation. See, also, **Pupil.**

Reaction, Perutz. A reaction in the serodiagnosis of syphilis. The patient's blood-serum is inactivated and 0.4 c. c. of it is drawn off with a pipette. To this is added 0.2 c.c. of each of the two following solutions: (*a*) sodium glycocholate, 2.0; cholesterin, 0.4; 95 per cent. alcohol, 50; or, this solution being diluted with water, 1: 20 parts, (*b*) a 2 per cent. aqueous solution of sodium glycocholate. The whole is shaken vigorously. If syphilis is present, fine flakes appear in the fluid.

Reaction, Quanti-Pirquet. The Pirquet reaction applied with a view to the amount or activity of the tuberculous infection.

Reactions, Bacterial. See **Seropathy.**

Reactions, Pupillary. The dilation, contraction and other reactions to light, accommodation and many other agents. See **Pupil in health and disease.**

Reactions, Serum. See **Serum reactions,** and **Seropathy.**

Reaction, Wassermann. The complement-fixation reaction applied to the diagnosis of syphilis. When the blood-serum of a syphilitic patient is mixed with an extract of the liver of a still-born syphilitic child, no reaction takes place; but if the patient is not syphilitic, hemolysis occurs. See **Wassermann reaction.**

Reaction, Wernicke's. See *hemiopic pupillary reaction,* p. 5767, Vol. VIII of this *Encyclopedia.*

Reaction, Wolff-Calmette. See **Calmette's ophthalmo-reaction.**

Reaction, Wolff-Eisner. Calmette's ophthalmic reaction.

Read, Sir William. An English ophthalmologist of the 18th century, concerning whom we know almost nothing. He wrote a book entitled *"Treatise of the Eye Containing a Short but Exact Description of the Structure, Situation . . . . . as also the Causes, Symptoms and Cures of 130 Diseases Incident to Them"* (London, 1706), copies of which are extremely rare.—(T. H. S.)

Reading, Care of the eyes during. See **Care of the eyes,** p. 1418, Vol. IV of this *Encyclopedia.*

Real focus. See **Focus,** p. 5236, Vol. VII of this *Encyclopedia.*

Real image. An image, whether due to refraction or reflection, each point of which is formed by rays proceeding from a corresponding point of the object. See **Image,** p. 6169, Vol. VIII of this *Encyclopedia.*

Rear-stop. In *optics,* a diaphragm with a circular hole centrally placed behind a lens-system in order to restrict the aperture to bundles of *effective rays* (q. v.). See, also, **Aperture,** p. 533, Vol. I of this *Encyclopedia.*—(C. F. P.)

Réaumer's scale. A thermometric scale, in which the freezing and boiling points of water are respectively marked 0° and 80°.

Reber, James Wendell. (The "James" was dropped in early life.) A famous Philadelphia ophthalmologist. Born at St. Louis, Mo., Apr.

3, 1867, he received the medical degree at Washington University in that city in 1889 (afterwards the *ad eundem* at Jefferson Medical College) and also practised general medicine at St. Louis for a number of years. It seems that his entrance into ophthalmology was very gradual, and not to be referred to any particular date. After a time he removed to Norristown, Pennsylvania, where he was long an interne in the Hospital for the Insane.

For about three years he practised ophthalmology at Pottsville, Pennsylvania. Removing to Philadelphia, his career as a specialist of international reputation was soon begun. He was professor of ophthalmology in the Medical Department of Temple University, professor of diseases of the eye in the Philadelphia Polyclinic; ophthalmologist to the Garretson, Samaritan, and Philadelphia General Hospitals; Fellow of the American College of Surgeons, honorary member of the Chicago Ophthalmological Society, past president of the American Academy of Ophthalmology and Oto-Laryngology. For several years he was a member of the Oxford Ophthalmological Congress, and in 1914 was the only American member of its Council. Socially, he was past president of the Meridian Club, a member of the Union League, Manufacturers' Club and Olivet Lodge of Masons.

Dr. Reber married, Jan. 6, 1902, Miss Jessie Dalrymple, of Philadelphia. There were no children. While attending the Memphis meeting of the American Academy of Ophthalmology and Oto-Laryngology, the Doctor was seized with pneumonia, and died, a few days later, at his home, 435 West School Lane, Philadelphia.

Dr. Reber was a man of medium height and weight, of a pale complexion, bright blue eyes and brown hair. He was, as a rule, vivacious in conversation, but was often slow, methodical and considerate about his work. He was one of the kindest-hearted of all men, and the writer regrets the impossibility of recording here a number of cases which have been reported to him (in one or two instances by the beneficiaries themselves) of assistance, financial and other, which Dr. Reber, in one or another extremely delicate manner, had offered to the younger, or more unfortunate, members of the profession. The Doctor's own early life had, in fact, been filled with great privations, which, however, instead of embittering him, made him as deeply tender as an elder brother toward the struggling juniors in his art.

Dr. Reber's tastes were catholic. More than merely an ophthalmologist, more even than merely a scientist, he was thoroughly versed in the lighter literature of several modern languages, in painting, in sculpture, and in architecture. He was fond of scientific gardening, and collected oriental rugs. He also collected many books, and loved

James Wendell Reber.

them as he did his friends, with all his soul. Though never a member of any church, he was, as a friend who knew him long has written, "broadly tolerant and charitable, and living every day a life that was near to God."

A letter from Casey A. Wood, of Chicago, to the *British Journal of Ophthalmology,* written shortly after Dr. Reber's death, contains one passage about the well-loved ophthalmologist which should be recorded here: "A telegram yesterday from Wendell Reber's secretary tells me of his untimely and sudden death from pneumonia. It was a great shock to me and robbed the new year of any modicum of joy it might otherwise have held. What a charming, laughter-loving friend we have lost! I knew Wendell intimately from the earliest period of his career and loved him—as almost everybody *did* love him—like a brother, and I shall miss him more than words can express."

Yet another communication was received by the journal named from Dr. Darier, of Paris. This, translated, is as follows: "I am astounded to hear of the death of our amiable Wendell Reber. What can have happened to him? He was so full of health and life when we saw him in 1914 at Oxford. He completely overcame me by his ardor for the work, by his faith in science, and by his great enthusiasm (so rare at the present day) for our recent therapeutic conquests. I shall always see him, his luminous ophthalmoscope in hand, running about, at Oxford, in the demonstration halls, in quest of interesting cases, sharp eyes on the alert behind the quivering eye-glasses, the prompt gesture, the precise word ever at the command of a judgment surprisingly clear and swift.

"How I loved his conversation, so full of unexpected and yet judicious appreciations.

"I saw him for the last time at my clinic in Paris, just a few days before the declaration of war, and in his last letter which I received from Philadelphia, he expressed to me his profound sympathy for the French, to whom he was related through his mother.

"Ophthalmology, in the death of Wendell Reber, has suffered a great loss, and all who knew him will remember him forever."

For the very long list of the Doctor's contributions to periodic literature, the reader is referred to the *Index-Catalogue* of the Library at the Surgeon General's Office. In conjunction with Dr. Howard F. Hansell, he wrote *"Muscular Anomalies of the Eye,"* a book well known to every ophthalmologist. He was Department Editor of *"The Ophthalmic Year Book,"* author of "Anesthesia, Local and General," in Wood's *"System of Ophthalmic Operations,"* and was one of the busiest and most esteemed collaborators on this *Encyclopedia.*—(T. H. S.)

Receptor. A hypothetical group of atoms of the cell molecule which has the power of combining with and anchoring the haptophore group of toxins, of amboceptors, or of cells. Receptors may continue to be attached to the cell or may be cast off in the serum, in either case retaining their combining powers. See p. 857, Vol. II of this *Encyclopedia.*

Rechteckig. (G.) Rectangular.

Récidive. (F.) Recurrence; relapse.

Recklinghausen's canals. Small lymph channels in the connective tissue which are regarded as ultimate branches of the lymphatic vessels.

Recklinghausen's disease, Eye changes in. MULTIPLE NEUROFIBROMATOSIS. Oscar Fehr (*Centralbl. f. prak. Augenheilk.*, Sept. 1913; review by Levy in the *Ophtholmoscope*, p. 291, May, 1914) says that Recklinghausen believed the affection to be a pure fibromatosis arising in the endo- and perineurium, and therefore he termed the growth neuro-fibroma. Verocay held that the tissue of these tumors was not fibrous but a peculiar neurogenic tissue, produced either by the nerve fibre cells themselves or their corresponding embryonal cells, and suggested the name neurinoma. The affection is therefore to be regarded as a malformation or as a disease of nerves upon a congenital basis. Recently Weichselmann advanced a toxic theory to explain the affection. He noticed the frequent association of this disease with osteomalacic changes, and came to the conclusion that disease of the glands with internal secretion, especially the pituitary, had something to do with this neurofibromatosis. There is at least a resemblance between this affection and some of the appearances in acromegaly and Addison's disease, and some of the visual disturbances in neurofibromatosis can be explained by changes in the pituitary.

The eye changes found depend upon the situation of the nerve changes, whether it be in the lids, the globe (ciliary nerves) causing buphthalmos, the orbit, or the interior of the skull. A unique case is that reported by Hirschberg in 1874 of a pericorneal tumor of this nature. It had been removed by A. von Graefe in 1865, but had recurred several times afterwards.

Fehr reports six cases, one with a postneuritic atrophy, one with retrogressive papillitis and some deepening of the sella turcica, one case of severe elephantiasis of the face and lids. The last caused considerable operative difficulty in forming a moveable eyelid, and at the same time bringing the palpebral fissure opposite the eye. Another case developed a thrombosis of one central vein, and in spite of a Krönlein operation, the site of the offending tumor could not be found.

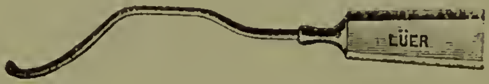
Reclination. The angle which the plane of a sun dial makes with a vertical plane which it intersects in a horizontal line.

Reclination of cataract. COUCHING. DEPRESSION OF CATARACT. An old method of operating for cataract by introducing a needle through the sclera just behind the ciliary region, passing it between the iris and the lens, and then depressing the lens into the vitreous till it lies at the bottom of the eye in a horizontal position with its anterior surface upward. See p. 1473, Vol. II, and p. 3544, Vol. V of this *Encyclopedia.*

In addition to this information the *Ophthalmic Year Book*, p. 223, 1909, notes that in a patient who had lost his left eye, and suffered from cataract and chronic purulent dacryocystitis in the right eye, Perez y Bufill depressed the cataract. The vision remained good two years later. Truc also reports a case in which on account of trachoma, purulent dacrycystitis and intraocular lesions, extraction was considered impracticable. After preliminary iridectomy he did depression of the cataract, and three weeks later the patient had vision of 1/10. Krauss, after a preliminary iridectomy, failed to extract the lens, because of liquid vitreous which promptly presented. Four months later he depressed the lens, obtaining vision of 4/40. This was lost after two years. On the other eye Krauss did extraction, using the Snellen loop, with a successful result. Kuhnt suggests that zonulotomy may be practised as a preliminary to reclination.

Reclinatio palpebrarum. (L.) Ectropion.

Reclinator, Basso's. This instrument (for the depression of cataract) is introduced through an opening previously made in the ocular wall. See cut.



Basso's Cataract Reclinator.

Reclusor palpebrarum. (L.) A name for the levator palpebræ superioris.

Reconstruction in ocular injuries. See **Injuries of the eye; War, Ophthalmic medicine and surgery in; Plastics,** p. 10255, Vol. XIII; **Military surgery of the eye;** as well as such headings as **Orbit; Blepharoplasty,** and **Re-education of the blinded.**

Recrudescence. A renewed or repeated acute condition of the disease after a decline or intermission.

Recruits, Visual requirements in army. See **Eyes of soldiers, etc.,** p. 5059, Vol. VII of this *Encyclopedia,* where the eyesight of American soldiers is in particular discussion. In addition attention is drawn to the paper of Paterson and Traquair (London *Lancet,* May, 1916) that contains a table showing the visual standard for recruits in the chief European armies. In France, Germany, Austria and Italy, the vision with glasses determines the acceptance or rejection of a recruit; whereas in Great Britain it is the vision without glasses which counts. This difference is due to the fact that up to the commencement of the present war, the British army was organized largely for foreign service at a great distance from its base, where there might be difficulty in providing proper-fitting glasses. In the British army, the standard for general service requires without correction vision of 6/24 in the better eye and 6/60 in the worse eye, which must be the left. In Germany combatants are required to have corrected vision of at least 6/12 in one eye, while in the other eye, the corrected vision may be minimal, and in the Landstrum the second eye may even be blind. In the armies of Germany, Austria, France and Italy, more than six diopters of myopia are allowed. So far as shooting is concerned, it is generally agreed that vision of 6/12 at least is necessary, and on the continent it is believed that a soldier with 6/12 vision wearing glasses is more efficient as a combatant than another with 6/24 vision without glasses. Continental authorities have found that on an average soldiers who see best shoot best, and that those who wear correcting spectacles shoot better than those who do not.

The authors conclude with the following summary:

1. The present sight test for general service for recruits for the British is by far the highest in Europe, and excludes from the fighting line large numbers of men who are freely used as combatants in the armies of the chief continental powers.
2. This is due to the fact that in the British sight test the vision without glasses (uncorrected vision) is what counts, whereas in the chief continental armies it is the vision with glasses (corrected vision) which counts.
3. In view of the present want of men there is urgent need for the immediate adoption of a remodelled sight test based on corrected vision, on the lines of the military visual standards in use on the continent of Europe.

Rectangle. A quadrilateral plane figure, having all its angles, right angles and its opposite sides consequently equal.

Rectiligne. (F.) Rectilinear.

Rectilineal. Composed of straight lines.

Rectilinear lens. A lens that projects an image in all respects similar to the object, an orthoscopic image. See also **Image**, p. 6170, Vol. VIII of this *Encyclopedia*.—(C. F. P.)

Rectilinearly. In a right line.

Recti (muscles). Four straight muscles attached to the back of the bony orbit, around the edges of the foramen through which the optic nerve passes, and running straight forward to their insertion into the sclerotic. See **Muscles, Ocular**, p. 7889, Vol. X; also p. 359, Vol. I of this *Encyclopedia*.

Recuperative extension field. In this form of the visual field its area enlarges after rest from fatigue.

Recurrence, Principle of. See **Principle of recurrence**, p. 10373, Vol. XIII of this *Encyclopedia*.

Recurrent erosion of the cornea. See **Injuries of the eye**, under the sub-section *Injuries of the cornea;* also **Cornea, Relapsing erosion of the**, p. 3438, Vol. V of this *Encyclopedia*.

Recurring optic neuritis. Under this caption H. Terlinck (*Ophthalmology*, p. 78, Oct., 1912) gives the history of a woman, æt. 25, with well marked syphilitic secondaries and double optic neuritis. The optic inflammation apparently followed intramuscular and other forms of injection of salvarsan on several occasions, and he believes the ocular affection to have been due directly in each instance to the treatment for lues.

Recurrent third-nerve paralysis. See p. 7697, Vol. X of this *Encyclopedia*.

J. F. Klinedinst (*Ophthalmology*, p. 35, 1912) refers to the rarity of the disease and mentions cases reported by deSchweinitz, Leszynsky, Sachs, Weber and Onuf and Posey, some typical while others are not true cases of recurrent oculomotor palsy. Various causes have been advanced by different authorities to account for this form of palsy.

From time to time, generally at regular intervals, a paralysis of the oculomotor nerve occurs which disappears after some days, weeks or months. Children are generally affected; a nervous predisposition was not noticed by most observers. There occurred with the paralysis, which generally attacked the same nerve (not passing from one side to the other), headache or pain in the eyeballs, the forehead, or the whole front of the head on the side of the paralysis, with nausea and vomiting. The headache generally had the character of migraine attacks, returning every four weeks or at longer intervals, and was almost always accompanied by the oculomotor paralysis. It is the rule that this begins the attack, and disappears when the other symptoms come on. In contradistinction to typical migraine, the headache and the vomiting may last for a week. This paralysis involves generally the whole oculomotor nerve; in some cases some of the branches were spared. The paralysis may even confine itself to the levator palpabræ superioris (Knapp). A decrease in sensation of the region supplied by the first branch of the trigeminal was observed in some cases.

There are cases of purely periodical and of periodical exacerbating (Senator) oculomotor paralysis. In the latter type a paresis of the nerve or of some of its branches, which may increase to total paralysis is present between the attacks; in the first we find nothing in the intervals. It also occurs that the paralysis disappears after the first attack, but persists partly later on.

We do not know anything positive concerning the cause of these symptoms nor the seat of the disease. Some, as Möbius and Brissaud, assume a nuclear disease; others, and the majority, a basal disease. In the cases which came to an autopsy (Gubler, Weiss, Thomsen-Richter, Karplus), the trunk of the oculomotor was found diseased; in one, a plastic exudate, in the others a neoplasm (tubercle, fibrochondroma, neuroma) was found. Many views are expressed—functional distrubance, local hyperemia, vascular anomalies, and the like, to account for the symptoms. The most plausible is that of Charcot, that periodical oculomotor paralysis is allied to hemicrania, and probably the latter, also, can be referred to vasomotor influences. A vascular spasm inhibits the flow of blood to the nerves, and thereby produces the paralysis; or the arterial nerves become paralyzed, and the overfilling of the vessels produces a corresponding compression of the nerves.

These attacks may recur many times without injuring the nerves. But in time a degenerative and inflammatory process takes place, which is not capable of complete retrogression.

It should also be understood that a circulatory disturbance recurring like this one can be the starting point for exudative processes and neoplasms.

Charcot emphasizes its intimate connection with migraine, and speaks of "migraine ophthalmopegia."

Fuchs believes that to the paralysis of basal origin belong most cases of periodic paralysis of the eye muscles. Such paralysis most frequently affects the oculomotorius. The attacks are ushered in by headache which is often associated with vomiting (ophthalmoplegic migraine). After these symptoms have lasted for some days, the paralysis sets in. After some days or weeks this either disappears entirely or leaves a paresis of the muscles that lasts till the next attack. The disease often begins in childhood and ends either in recovery or in permanent paralysis. Some of these are of purely functional nature (hysterical). In others there is a basal lesion, a circumscribed exudate or small new-growth that presses on the nerves.

Recurvate. Curving backward.

Red, Scarlet. A. A synthetic dye, the sodium salt of disulphonic acid: used as a differential stain for fat. B. A synthetic dye, said to be amido-azotolueneazo-B-naphthol. It has been employed locally to produce epithelial growth in ulcer and other conditions causing skin deficiencies. Called, also, *Biebrich-red* and *fat-Ponceau-red.* It has been used in ulcerative blepharitis and corneal ulcer. See p. 3466, Vol. V of this *Encyclopedia.*

Red-blindness. See p. 2427, Vol. IV of this *Encyclopedia.*

Red-eye. RUDD. A fish belonging to the same genus as roach, chub and minnow. It much resembles the roach, but is shorter and deeper. It is richly colored, the name rudd referring to the color of the fins, the name red-eye to that of its iris.

Redi, Francesco. A versatile and distinguished Italian poet, naturalist-historian and physician (1626-1697) who became professor of medicine at Pisa and body-physician to Cosmo II of Tuscany. He is especially to be remembered for his investigations into the nature of viper's poison and into the manner of reproduction of the lower forms of life.

He is of interest to ophthalmologists, however, chiefly because of the light he sheds on the first employment of spectacles, or indeed of lenses of any form used for the betterment of vision. Thus, quoting from a manuscript work in his possession, dated 1299, and entitled, "Trattato di governo della famigli adi Santro di Pipozzo di Sandro ittadino Fiorentino fatto nel 1299, assemprato da Vanni del Busca Cittadino Fiorentino suo genero," he has preserved for us of to-day the following passage from the "Introduction": "I find myself so burdened by years that I have no power to read and write without the glasses which are called eyeglasses and which were recently invented for the convenience of poor old men, when they become weak in sight." Redi also quotes from a sermon of Giordano da Rivalto, preached at Florence Feb. 23, 1305, the following interesting passage: "It is not yet 20 years since the art was discovered of making eyeglasses, which give the power to see distinctly, which is one of the best and most necessary arts which the world possesses."

In both these passages, however, not the invention, but the re-invention of "eyeglasses" was the fact in the minds of the original writers. See, on this point, **Spina, Alexander de**; as well as p. 4894, Vol. VII of this *Encyclopedia.*—(T. H. S.)

Red light as a danger signal. See p. 2473, Vol. IV of this *Encyclopedia.*

Red precipitate. See **Mercury, Red oxide of,** p. 7655, Vol. X of this *Encyclopedia.*

Reduced eye. SCHEMATIC EYE. An imaginary eye in which the compound dioptric system of the human eye is reduced to a single refracting surface, bounded anteriorly by air and posteriorly by aqueous or vitreous humor. Where very great accuracy is not required, this reduced eye may be made the basis of a number of considerations and calculations. See **Physiological optics,** especially p. 9755, Vol. XIII; also, **Listing, Reduced eye of,** p. 7498, Vol. X of this *Encyclopedia.* See, also, **Schematic eye.**

Reducibility of the globe. Langenhans (*Oph. Review,* p. 32, Jan., 1911) discusses the degree to which an eye can be pushed back into the orbit against the resistance of the orbital tissues and claims that it may have an important diagnostic bearing in certain cases; hitherto one's finger pressure has been one's only guide. The diagnostic point might be very important in cases of doubtful tumors of the orbit, of Graves' disease, etc. The author has devised an instrument standing on three adjustable feet, to which is attached a cylinder of aluminum. By means of this device pressure is effected upon the closed eyelid (not upon the cocainized cornea). The instrument registers the amount of change of position which takes place with a given weight in a given space of time. So far as reported the use of the instrument has been limited by him to physiological conditions. In 57 cases of healthy eyes Langenhans has found that a pressure of 100 grammes gave an average displacement of 4½ mm.; doubling the pressure gave an average displacement of 6½ mm.

Red-vision. ERYTHROPSIA. See p. 4519, Vol. VI of this *Encyclopedia.*

Reed. *Calamagrotis lanceolata.* Reed-ashes, in the time of Archigenes, were employed in madarosis (q. v.) with a view to the reproduction of the cilia. They were usually mixed with the dung of goats and mice, and with a number of other substances.—(T. H. S.)

Re-education of the blinded. REMAKING OF THE WAR BLINDED. VOCATIONAL RECONSTRUCTION OF THE BLINDED. This section should be read in conjunction with **Institutions for the blind,** p. 6372, Vol. VIII of this *Encyclopedia,* as well as with most of the **Blind** and **Blindness** headings in Vol. II. (See, also, **Reconstruction.**)

The conception of a blind man returning to his usual social duties so equipped industrially that he can compete on equal terms with his sighted fellow citizens was put in practice for the first time during and after the Great War, 1914-1919. Consequently what follows is essentially new and has not been fully considered heretofore in this work. The first portion is taken almost verbatim from

The Disabled Soldier (Macmillan and Co., p. 120, 1919), edited by Douglas McMurtrie, one of the authors of the section on **Institutions for the blind** in this *Encyclopedia*. It was written by Lieut. Col. Jas. Bordley Jr., Director of the Red Cross Institute for the Blind at "Evergreen," the country estate of 99 acres and large buildings given by Mrs. T. Harrison Garrett to the government through the Surgeon General of the Army, and situated near Baltimore, Md. The chapter in question was written with the cooperation of Chas. F. F. Campbell, another contributor to the section on **Institutions for the blind** (in the United States), Superintendent of the Ohio State School for the Blind and assistant at "Evergreen" to Col. Bordley.

These writers remind us that blindness is a very serious handicap, the intensity of which cannot be minimized. This is especially the case with the loss of sight occurring in adult life, as with the blinded soldier. With all his activities organized on a sighted basis, the new limitation seems crushing. Yet there is a way out of the darkness to happiness, and it is our sacred duty to help the blind veteran to find that road.

This obligation has been well stated by Eugène Brieux, who has taken a deep interest in the war-blinded of France. "For some wounded soldiers our responsibility is over when their wounds are healed, but for the blind it then only begins. Blinded soldiers have been reduced to a state of disadvantage to other men; they have become again children, before whom stretches the possibility of a happy life, but who must be initiated into this new life. They have need of treatment other than physicians can give, of other aid than consolation and kindness. They need to be prepared for their new life—to be armed for the struggle upon which they are entering. It is true that they enter the struggle less enfeebled than one would think, far less than they themselves believe, but their capacities are of a different kind from what they were before, and the period of adaptation is hard." During this period, those privileged to care for the blinded soldier will need all the tact and skill at their command.

Fortunately, the number of soldiers suffering from loss of sight, total or approximate, is comparatively small. According to British statistics injuries to sight account for but two and eight-tenths per cent. of the disability pensions granted. In the Canadian forces up to date there have been blinded less than one hundred men. In France about 1.2 per cent. of all major disabilities was blindness in one or both eyes; total blindness in both eyes about one-tenth of one per cent; somewhat more than the American experience.

In starting with the blinded soldier there are two primary requirements. The first is to overcome the deep discouragement in which the man is likely to be plunged. The second is to teach the blind soldier how to accomplish the little everyday tasks which make life possible and comfortable. The first of these goes with the latter, for as the man learns how to take care of himself and get about with some facility, hope begins to return. In these early stages another blind man is the best teacher, and will succeed where the sighted fail. Sometimes a fellow warrior who has himself been blinded, but has already had his start, will be most effective of all. The first blinded American sailor who returned to our training center at Baltimore was so far depressed that his case seemed hopeless. Nothing could be done with him until there was put on the job the first blinded American soldier, who had an earlier start and had already "seen the light." His companionship and encouragement turned the trick, and of course the advantage was reciprocal.

All along the course of re-education the blind can be of the greatest assistance to these sightless soldiers. They make good teachers for, when they argue that a thing can be done, it is likely to carry conviction. They know whereof they speak.

Another necessity is teaching the families to have a blind member, and be helpful to him rather than the reverse. The American program for re-educating the blinded soldiers provides for bringing the families of the men to the training school for a visit, so that they may become acquainted with and understand the methods by which the men are led to be independent. If when the man returns home the family immediately discourages his ever moving out of his chair, insists that he will stumble if he walks about the house, and brings everything to him, they will be destroying the good accomplished during his training. It has been well said that "they should not place him in a corner out of reach of all danger like a feeble old man or a child in swaddling clothes." They must rather tactfully encourage him to do more and more for himself and urge him to get up and about. They must be prepared, in a word, to continue his re-education.

Blinded soldiers must be protected during their period of training against the visits of curious but well-meaning people, whose ill-advised remarks will do more harm in a few minutes than the benefit which a teacher will impart in as many days. Several French schools have prominently displayed this notice: "To pity is not to console! Only words of hope and confidence should be spoken here."

Recreation is an important factor in the social treatment of the blinded soldier. One of the primary methods of entertainment—with instruction combined—is reading aloud to a group of men. At one of the oldest schools for the blind in Paris a daily newspaper is read from each morning, the choice of the journal being determined by vote of the auditors. Music is another means, and the blind should be encouraged to take part in group singing. Many athletic games of considerable vigor are entirely within the reach of the blind, and almost any form of gymnastic work is practical.

For inside recreation there are playing cards with raised symbols of identification, dominoes with the dots raised instead of sunk, and sets of checkers with the black pieces square and the red pieces round.

The first educational necessity for the blinded soldier is the learning of Braille. Fortunately, in this country and Great Britain the divergencies of opinion which were responsible for the existence of several alphabets have been reconciled and there has now been adopted a standard type. Learning this the blind man will be enabled to continue his reading or study to keep posted on current developments through a monthly magazine in raised letters, and correspond with his friends. He may himself write either in embossed print or, with the aid of a guide to keep the lines straight and regular, with pencil or pen. He should be encouraged to do the latter so that he may not forget how. With men who were illiterate before they became blind the matter of teaching them to read and write Braille is not so important. See **Alphabets for the blind,** Vol. I of this *Encyclopedia.*

In the past, the blind, like the crippled, have suffered from the conception that the only occupations within their capabilities were those of basket-making, chair-caning, and other similar handicrafts. Almost no schools had attempted teaching the more highly-skilled specialties. Yet the few experiments which have been attempted, and the instances where ambitious blind men have made places for themselves, show that well-paid occupations are not closed to the sightless. A few examples will show the manner in which the problem is approached.

In a large factory making an ignition and lighting system for automobiles, much expert assembly work is performed by a man totally blind. Is this man, who does all his work by sense of touch, under any handicap in competition with his sighted colleagues? As a matter of fact, he is probably a more faithful workman because he appreciates the opportunity of his job, and is likely to turn out a better day's product that the man next to him because he will not be distracted by looking out of the window at things going on in the street.

In a clock factory which uses as gongs spiral coils of tempered wire it is necessary accurately to test and adjust the tone of each gong.

This is done by striking the coil, listening to the result, and then making the necessary change by a screw sleeve at one end. In this job which requires the use of two senses only—touch and hearing—is a blind man at any disadvantage after he has acquired skill for this work?

The first attempt in planning occupations for the blind is to send them back to their former trade, if this is in any way possible. And it will be found practicable in more instances than would be imagined. In actual experience competent blind workmen will be encountered in almost every line of employment.

Two satisfactory occupations which are almost traditional to the blind are massage and piano-tuning. Men who have been trained in the first subject have gone back to employment in military orthopedic hospitals, where their patients are fellow-soldiers injured in other ways. The period of training is fairly long and the work only suited to men with certain qualifications, but for those who can learn to be good masseurs, employment is secure and earnings good. In Japan the practice of massage has been reserved as a monopoly for the blind. Piano-tuning is for many blind men an excellent business, but it is a crowded field and care must be taken not to train for it too many novices.

Men employed in clerical lines before the onset of blindness can be trained, with the aid of a few simple devices, to continue their office job.

Many blind soldiers who come from the farms can most advantageously return to the same work. The man without sight is in many ways better off in the country, where he can get around with little difficulty, without the need of a guide, and with small risk of accident. In addition the national interest is served by his continued activity as a good producer.

It may appear at first that a blind man could not get on at all in work about a farm. But note the evidence in a letter from a blinded French soldier:

"A man used to working on the farm, even if he is totally blind, can do practically everything around the barns and stables, if he is not lazy or stupid. He car clean up the yards, go for water, rub down the horses and cows, and feed all the animals. It is not hard to recognize with your hands the linseed mash, the barley, and the bran or the oats, and to know also through your hands when the racks and mangers are full, and, when you come back later, to still tell by your hands whether the animals have eaten. You do not need to see to tend the winnowing machine, to help in putting the grain into sacks, and then to put the sacks in the wagon. You can cut up beets for the cows, too, and you can help in making bread for the family, for in our part of the country bread is made in the house.

"The work in the field is harder, I admit, but there are lots of tasks which you think at first are quite impossible—you would have laughed in the old days if anyone had told you a man could do them without seeing—but which now after three or four attempts, after three or four failures, perhaps, you finally accomplish. You can easily dig beets and potatoes, unload wagons, and in the season thresh and spread the hay. I can't mention everything, of course, but there you have already quite a list. In addition, when it rains and you have time on your hands, you can make brushes, as you learned to do in the hospital. I should never have believed that I could be as contented as I am now."

At present the best known institution in the world for blinded soldiers is "St. Dunstan's," in Regent's Park, London. In a fine old house set in the midst of fifteen acres of beautiful land, are housed the British soldiers who have lost their sight in battle. Its "heart and soul" is Sir Arthur Pearson, who lost his sight several years ago and who has devoted his life to the task of "teaching men to be blind," as he expresses it.

Shortly after the war began (1914), Sir Arthur, then president of the National Institute for the Blind, organized the Blind Soldiers' and Sailors' Care Committee, which set about to find a suitable building where blinded soldiers might be trained. The selection was St. Dunstan's, generously placed at the disposal of the committee by Mr. Otto H. Kahn who had the lease of it at that time. The building was once the country house of the wicked Lord Steyne of Thackeray's *Vanity Fair.*

On March 26, 1915, fourteen blinded soldiers entered St. Dunstan's Hostel to start on the journey to self-support and hope. Three years later St. Dunstan's and its annexes held 578 men, after having graduated 434, of which number ninety per cent. had been fully trained and set up in the occupations which they had learned in the school.

The notable feature of St. Dunstan's is its cheerful atmosphere. After the men have surmounted the first few days of depression brought on by the thought of "living always in the night," they look out for themselves and go about like normal men.

The blinded guests have very little difficulty in getting about at St. Dunstan's. They manage to find their way without the aid of a stick and without being led by the hand. This they are enabled to do by a unique device. Strips of carpet of even breadth run through the center of every room. As long as they can feel the carpet under their feet, they know there is no danger of their running into any obstacle. A visitor at St. Dunstan's relates that two men bumped into each other as they were walking in opposite directions on the same strip, but exchanged greetings merrily and continued on their way as if nothing had happened.

To guide the men when they go about out of doors, other devices have been arranged. On the top and bottom steps of stairways, wood or lead strips are fastened to tell the men where they are. Along the paths leading to the various outlying buildings, railings are placed, with little knobs to tell the men when they come to a turn in the road.

There are amusements such as rowing, swimming, dancing, indoor games—such as dominoes, checkers, chess and cards; they have a debating society, and almost every man learns to play some kind of musical instrument. They have their theatrical clubs and recently gave an excellent performance of "Babes in the Wood."

But it is not all play at St. Dunstan's. The actual re-education and training are carried on in either classroom or workshop. Those who are assigned to the workshop in the morning are in the classroom in the afternoon, and vice-versa. The working day is from 9:30 to 12 in the morning, from 2:30 to 4:30 in the afternoon, with an optional extra hour for those who wish it.

The classroom work consists largely in the teaching of Braille and typewriting. The men are taught to read and write Braille, both arts very difficult to acquire and involving considerable strain on the mental faculties. To relieve this, the Braille lessons are interspersed with netting, which is something of a hobby, at which a man can make in his spare time five or six shillings a week.

All the men are taught typewriting, which they find enjoyable and at which they usually become very proficient.

Affiliated to this classroom work are three occupations, the successful performance of which requires a knowledge of Braille and skill in the use of the typewriter. These are massage, shorthand, and telephone operating.

To learn massage requires a knowledge of Braille, because many of the books on anatomy and physiology have been put into raised type. Blinded men have been trained as highly-skilled masseurs at St. Dunstan's. Shorthand for the blind is a system of condensed Braille, and is written by means of a special little machine. Telephone operating on boards operating with drop signals rather than lights is successfully taught.

In the workshops at St. Dunstan the men are taught cobbling, mat-making, basket-making, and joinery. Most of the instructors are blind and thus furnish an inspiring example for the pupils.

On a spacious poultry farm, beyond the workshops, men are taught poultry raising on modern scientific lines. They learn to distinguish by touch birds of various breeds, to manage incubators and foster-mothers, to prepare and truss birds for the table, and in general to conduct a paying poultry business. The pupils are also taught rough carpentry, so that they can make hen-coops, setting-boxes, gates, and other farm essentials. A post-graduate course in poultry farming, so to speak, is given at St. Dunstan's Poultry Farm, near King's Langley, and is a month in duration.

Wherever possible a man is returned to his former trade or occupation. It has been possible for men to resume their employment by giving them special courses of instruction or by teaching them special methods. When a man completes his training at St. Dunstan's, he is settled in the trade that he has studied, is equipped with an outfit and with an abundant supply of raw material. Through a carefully organized after-care system, he is visited regularly, his work is supervised, raw material is supplied to him at cost, and he is assisted in marketing his goods.

Graduates of St. Dunstan's earn a fair living wage. It must be remembered that the blind soldier with an earning capacity is enabled to augment his pension, which is not affected by increase of income, as his skill and earning power increase.

In France at the beginning of 1915, when it became clear that the number of blinded soldiers was going to be considerable, the Ministry of the Interior created a special institution for them in an old building in the Rue de Neuilly, Paris. All the war blind were to be sent there when their medical treatment was completed. Accommodations were provided for two hundred persons. The first group, admitted in March, 1915, consisted of forty men. But soon the home was filled to capacity, and seventeen branches have since had to be created: three in Paris, two in Lyons, and one in each of the following cities: Amiens, Bayonne, Bordeaux, Caen, Chartres, Dijon, Marseilles, Montpellier, Nantes, Saint-Brieuc, Tours, Toulouse.

This institution is under the control of the Ministry of the Interior. Since its creation, however, it appeared to the director that, in addition, private initiative might be advantageously organized. He created the Society of Friends of Blinded Soldiers, formed of representatives of the Ministries of the Interior and of War, of Parliament, of the Quinze-Vingts hospital for blind, of the teaching profession, of commercial circles, and of the Catholic, Protestant, and Jewish interests. It was through the efforts of this society that the different activities of the institution have developed.

The Neuilly home was created as a "Convalescent Home for Blinded Soldiers," without any precise idea as to what it was to do for its inmates. It was but gradually and empirically that the re-education work has been built up. One month after the inauguration of the home, a very small shop for brush-making was opened. The experiment was successful, and the brush-making shop was soon overcrowded. It is still the most popular with the men. Since 1915, however, the re-education work has greatly expanded by the addition of new trades.

At the present writing there are taught at Neuilly all the standard trades for the blind—brush-making, basket-making, making and repairing of chairs, and so on. The course in massage, which has been a marked success, consists of two sections: massage proper and theoretical instruction in anatomy and physiology. The latter includes a complete course of lectures which it is necessary to write in Braille; ability to read by touch is a prerequisite. At the end of the course, the students have to pass a very strict examination before a jury of physicians; they are never discharged before receiving their diploma. Since February, 1917, a group of graduates from Neuilly have been employed as masseurs in the military hospitals of Paris, and have given great satisfaction to the medical authorities. Others have found employment at the different resorts, at Monte Carlo, Vichy, Evian, Deauville.

A shoe-repairing shop was established in February, 1916. The work was first confined to pegged shoes, but later an invention of one of the students made possible hand-sewn work also. Several men have graduated and found employment. The first pupil of the shoemaking school is now employed as an instructor in a workshop for blind civilians.

A machine shop, under the direction of a blind instructor, has been in operation for two years. The first twelve pupils are now working in a special shop created for war blind. This shop is now filling orders for several of the largest automobile and machine plants.

A course in piano-tuning has been started on the initiative of a prominent piano manufacturer, himself blind. Other courses are in crystal grinding and telephone operating. Organ-playing and singing are taught, not as independent vocations, but as possible supplementary occupations. Macramé (a kind of coarse lace), raffia, and netting are not considered as real trades, but are taught to new arrivals for distraction and as a first preparatory exercise.

As a general rule, all the men learn to read Braille. There has been established at the home a printing shop in which books in Braille are produced. To interest the men in reading, there is distributed every morning the official war bulletin printed in Braille. Still more effective in stimulating interest, has proved the publication of the *Neuilly-Midi*, a small daily, which contains all the news of the institution.

Many of the men learn typewriting, although it is not intended to train them for positions of typists. For the use of those who wish to correspond in ordinary handwriting, the administration of the home has devised a very simple "hand-guide," which permits the blind to write on equidistant straight lines.

A very surprising experiment, which has given excellent results, is a course in fencing, directed by an expert teacher.

In Germany, where a number of institutions for the training of the blind had existed before the war, the general policy was that of creating in these institutions special sections for blinded soldiers. One of the most important institutions of this type is that at Breslau, which accommodates about fifty men. The men are transferred to the school after their medical treatment has been completed and stay there for about three months. They are kept under military discipline, and the training is compulsory. Many of the men remain in the institution voluntarily after being discharged from the army; in that case they contribute one mark a day, out of their pension, for their maintenance.

One year is considered as the average length of time required to teach a blind man Braille and one of the standard trades for the blind, such as basket-making, brush-making, rope-making, and the like. Of these occupations, basket-making of the rough type is the most popular with the men, especially those of country origin. It must be remembered that there is a much wider demand for hand-made baskets in France than in America.

Effort is often made to return the man to his former trade. The experience has been successful with several men, former bakers, cigar-makers, watch-makers. In addition to the trades taught at the institution, a number of men have been placed for training in industries, such as munition plants, clothing factories, and so forth.

In connection with the institution there has been established an agricultural training station, intended mainly for peasants. It seems, however, that the blind soldiers of the agricultural class consider any special training as superfluous and are anxious to return to work on their own farms as soon as possible.

The greatest difficulty arises with regard to men belonging to the intellectual classes. Most of them, however, are officers, and the relatively larger amount of their pension permits them to supplement the instruction given at the institution with private lessons. Many have been able to return to their former professions, as lawyers, teachers, and the like, or to resume their academic studies interrupted when they went forth to battle.

As a result of several years' experience in re-educating the war blinded in France Ginestous (*Jour. Am. Med. Assocn.*, p. 606, Aug. 17, 1918) declares that every minute is precious and not one should be wasted, from the beginning, to train the suddenly blinded, for he is like a babe just born into a new world. From the very first, while still in the eye infirmary, his training in writing with a guide frame and in reading the Braille type should begin, without waiting to ascertain whether vision is entirely lost or not. A small broom- or brush-making plant is now connected with each centre d'ophtalmologie. Even if vision is regained later, these exercises do no harm but fill up the leisure moments, while if total blindness is unavoidable, precious time has been saved. In his own service, Ginestous has been amazed at the rapid progress made by the men. In a few hours they learned to write with the aid of the frame. The Verdon-Richard guide-mains seemed to give the best results in this line. All the men could read and even write the Braille fluently by the time they left his service.

Referring more definitely to re-education of the war blinded in the United States Bordley (*Journ. Am. Med. Assocn.*, June, 1918) points out that the Surgeon-Generals of our Army and Navy have combined forces, and together will educate the soldiers, sailors and marines. This education is given them in a military training school for the blind, which is located on a magnificent estate in Baltimore. The school is conducted by the best teachers of the blind in this country. It has every appliance available in the development of the powers of the blind. When they complete their courses in the school, trial employment is given them.

The blind are divided into five classes: those who can work at home, those who can work in blind shops, those who can enter industry, those who can go into agriculture, and the professional classes. No blind man will leave until he is fully prepared to go to work.

It is proposed to utilize the services of every individual and of every organization which can help in this splendid work. The American Branch Belgian Blind Relief Fund has assisted in a most substantial way, bringing over $100,000 with which to conduct a certain portion of the work. The American Red Cross, at the request of General Gorgas, has authorized the organization of the Red Cross Institute for the Blind. This Institute will supply the necessary economic and social supervision for our soldiers, sailors and marines from the time of their discharge from the Army or Navy until they die. This supervision is not to be a charity but a helpful moral support. This Institute has organized a purchasing department through which will be bought in quantity, at wholesale rates, the raw materials used by the blind in their homes. They have organized a selling department, because one of the great disadvantages of the blind who work at home is the limitations of their market. This selling agency is to take charge of this work of selling the finished products of the blind. It has also a savings association, because one of the greatest difficulties the blind man has is to get the means wherewith to make his initial investment in material, machinery and tools. This savings association will not only take the man's money, properly invest it and safely keep it for him, but when the time comes for him to work it will be behind him financially and help him wherever he needs help.

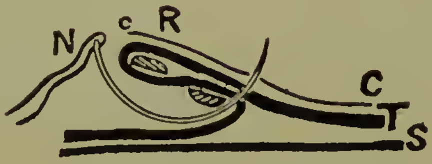
"We recognize," says Bordley, "that the blind man has three serious difficulties to overcome before he can make his own living: The first difficulty is his own timidity, the second is the misplaced sympathy of his family and friends, and the third is the reluctance on the part of industry to employ him. To overcome his own handicap, we are going to educate him. To help the family to realize the man's ambitions, the man's troubles, to see the necessity for their moral support in his work, we are going to take one member of the man's family to Baltimore and educate her side by side in our school with the man himself. We propose to keep that member in Baltimore in the house that will be conducted by the Red Cross institute at no cost to the family. To overcome the difficulty of the reluctance of industry to employ the blind, we propose to help the blind man demonstrate to industry that he can take his place and do his part. On account of the present geographic distribution of the Army we are obliged to have two services or plans of work, one in France, and the other in this country. The service in France, so far as blind men are concerned, begins when the man gets back to his base hospital." The writer says that there is no intention of going forward to that hospital in order to teach the blinded men or to help them, but to begin with the service in the base hospital. In that hospital no serious attempt will be made to teach the man how to help himself to make a living. He will only be taught there how to amuse himself. There will be professional instructors, people who can teach him how to play games. Then when he is through with his base hospital treatment and surgical treatment he goes back to the special hospital center which has been designated as the point of concentration for the blind. In this center there will be a field director for the blind, who will have supervision over all the work throughout the whole of France; under him will be instructors. In this hospital they will go a little further than in the base hospital, and will try to teach him reading and writing and games; in other words, to begin the serious work of making the man realize that he has abilities that can be developed; to teach him how to shave and dress himself, how to walk with a cane, how to play games, how to write his own letters, and how to read books for the blind.

Then comes the port of embarkation and ocean transportation. Here are helpers or teachers for the blind, who will also teach the men with other handicaps who will come back on the same ships with the blind, so that they can take care of and amuse them also. Thus there will be no point of transition between their work here and their work there; there will be no two weeks of monotony in which they can deteriorate, which of course with the blind is a very serious handicap.

Then follows the service in the United States. The men come to the port of embarkation; afterwards into the hospital for distribution. They are summoned before a special examining board which acts as a vocational board. If this board finds that the man's injuries are permanent and nothing can be done for him, he is sent over to our blind-teaching school in Baltimore. If they find that he has still efficiency they may send him to a reconstruction hospital. After he has had his surgical work done there and it is found that it is impossible to do anything further for him, he goes to the blind-teaching center. This is a military department and has its instructor, who is experienced in handling the blind, and chosen on account of his particular fitness and adaptability. Under him are teachers, schools and shops of the mechanical and vocational type.

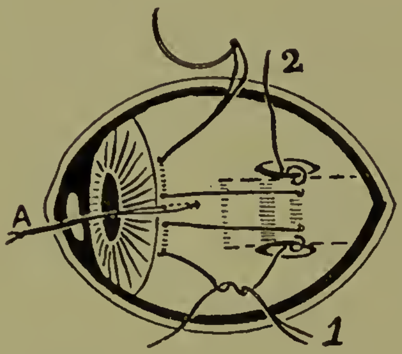
After the man finishes his work at the schools one comes really to the practical training. After he undergoes his practical training he gets training in professional work, commercial work, the trades or agriculture. After that is done he will take a course in the Institute for the Blind, and they will follow him in his work to his home for the rest of his life, making sure that his wants are satisfied.

Reefing operation. This is one of the methods of advancement employed to relieve oculomuscular defects. See p. 8220, Vol. XI of this *Encyclopedia.* The method of Harman (*Proc. Royal Soc. of Med.*, June, 1913) is depicted in this text, the legends sufficiently explaining the steps of the procedure. See, also, p. 8230 and p. 8236, Vol. XI of this *Encyclopedia.*



Harman's Reefing Operation.

Path of needle through base of reef. N, needle; CC, Conjunctiva; R, reef; S, sclera; T, tendon.



Harman's Reefing Operation.

Tendon reefing with advancement. Sutures 1 and 2 carried forward and into sclera before tying. A, anchor stitch.

Reef knot. Sailor's knot. Square knot. A double knot in which one end of the cord in the second knot is passed over or under the other in the reverse of their relation in the first knot.

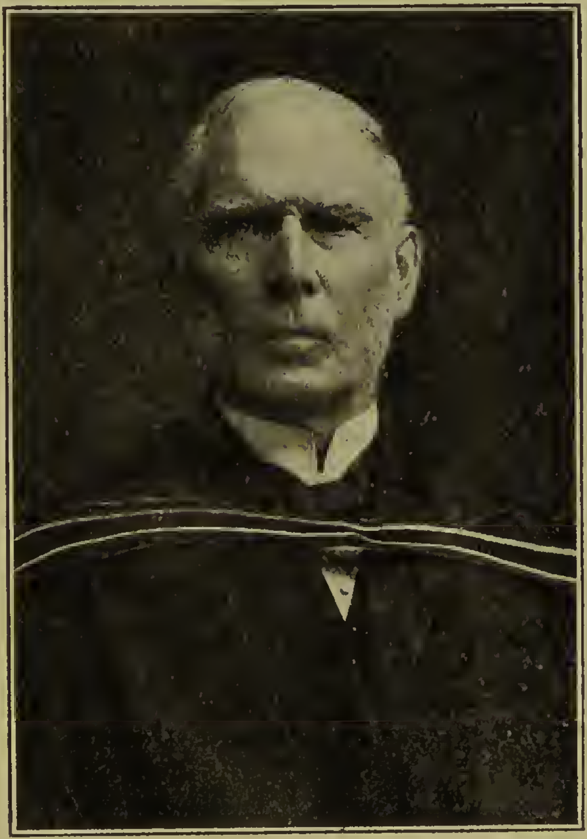
Re-entrant angle. Re-entering angle. An angle of which the apex is towards the interior of the figure in which it occurs, or of which the apex recedes with reference to the point of view from which it is considered.

Reese's muscle resection operation. See p. 8233, Vol. XI of this *Encyclopedia.*

Reeve, Richard Andrews. A prominent Canadian ophthalmologist. Born in Toronto in 1842, son of William R. Reeve, he received the degree of B. A. at Toronto University in 1862, winning the silver medal in Natural Sciences. In 1865 he received the M. D. at Queen's University, Kingston, and, again, in 1889, at the University of Toronto. He became a Fellow of the Royal College of Physicians and Surgeons in 1866.

From 1865 until his death, 55 years later, he practised continuously in Toronto, excepting when engaged in study for the *ad eundem* degree. In 1867 he began to devote his attention exclusively to diseases of the eye and ear.

For many years he lectured on ophthalmology in the Toronto School of Medicine, and, from 1885 until his death, on ophthalmology and otology in the University of Toronto. In 1890 he was chosen Dean of the Medical Faculty, a position which he resigned in 1908. He was made chief of the eye department in the Toronto General Hospital in 1907. He was also, for a time, a member of the Toronto University Council and of the Board of Regents of Victoria University.



Richard Andrews Reeve.

Dr. Reeve was once president of the Canadian Medical Association, and was president of the British Medical Association when it met at Toronto in 1906. He was a delegate to the British Medical Congress in 1910 and from 1904-7 president of the University Alumni Association. He was also a Fellow of the American College of Surgeons. He was an active member of the Central Methodist Church.

Dr. Reeve died suddenly on Jan. 27, 1919, at Harbord Street and Spadina Avenue, Toronto. Mrs. Reeve had died about two years before, and the only surviving relatives are two sisters and a brother, Dr. J. Reeve, of Deland, Florida.

Concerning the personality of Dr. Reeve, a writer in *The Canada Lancet* gives us the following: ''His was one of those quiet, subtle influences that took a hold of one; and once it laid hold, grew. No one ever heard a rude or coarse remark fall from his lips. He was most deferential to the opinions of others, ever seeking to promote the welfare of his profession, always ready to act in any capacity his confrères sought his aid, and always displaying a keen insight into the questions brought before him. His humor, too, was of the most delightful character. . . . Dr. Reeve was both an example and an inspiration. He belongs to the future as well as the past.''—(T. H. S.)

Refixation. The recovery by a second effort of the fixation and percipient apparatus of the point of regard.

Reflected ray. In *optics,* a ray of light whose direction is the result of the arrested initial direction of the incident ray at the point of impact to a surface. As the incident and reflected rays form equal angles with the perpendicular at the point of incidence, it follows that the incident ray is returned to its source as the *reflected ray* when the former is perpendicular to the reflecting surface. All objects are capable of emitting reflected rays to a greater or lesser degree, and which accounts for their being made visible.—(C. F. P.)

Reflecting camera. A form of camera obscura.

Reflecting goniometer. An instrument for measuring the angles of a crystal by means of the deflection of a ray of light incident on its surface.

Reflecting microscope. A microscope, in which the object, placed either outside the tube or outside the axis of the tube, is reflected by means of an inclined plane mirror.

Reflecting stereoscope. A stereoscope wherein the superposition of the views respectively adapted to the right and left eye is affected by means of mirrors or reflecting prisms.

Reflecting telescope. A telescope wherein the rays proceeding from the object viewed are focused by means of a concave mirror.

Reflection. A surface on which a beam of light falls may be either rough or smooth. If it be rough, the greater part of the incident light is irregularly scattered by the innumerable surface-facets, so as to be reflected or dispersed in all directions; if it be smooth, a proportion (but never the whole) of the incident light is regularly reflected or turned back in definite paths. A smooth, dustless mirror is not visible to an eye outside the track of rays reflected from it. If the polished surface be that of a transparent substance (e. g., glass) optically denser than the medium conveying the light to it, comparatively little light is reflected; but the more oblique the incidence, the smoother the polish, and the greater the difference between the optical density of the glass and that of the medium in which it is immersed, the greater proportion reflected. Thus less light is reflected from glass under water than from glass in air; and conversely, if the light travel in the denser medium and strike the bounding surface between it and a rarer medium as where light ascending through water strikes its upper free surface—it will, if its obliquity of incidence exceed a certain limit, be almost totally reflected; the small loss that ensues arising wholly from absorption, while no light is transmitted into the air above.

On reflection from polished surfaces we have, so far as regards the directions of the reflected rays, the following laws: (1) The incident "ray" the normal (i. e., a line drawn perpendicular) to the surface at the point of incidence, and the reflected "ray" all lie in one plane, the "plane of incidence"; and (2) the angle of incidence (the angle which the incident "ray" makes with the normal to the reflecting surface) is equal to the angle of reflection (the corresponding angle between the normal and the reflected "ray"). These laws apply equally to ether-waves of all lengths, and therefore to light of all colors; and they also hold good whatever be the shape of the surface. They are a necessary kinematical consequence of the principles of wave motion and apply to the reflection of all kinds of waves.

Plane reflection surfaces. (1) Rays which are parallel to one another before striking a plane reflecting surface are parallel after reflection. (2) If light diverging from or converging towards a point be reflected from a plane mirror, it will appear after reflection to diverge from or converge towards a point situated on the opposite side of the mirror and at an equal distance from it. (3) A consequence of the preceding proposition is that when an object is placed before a plane mirror the virtual image is of the same form and magnitude as the object, and at an equal distance from the mirror on the other side of it. The right hand of the image, taken as looking towards the mirror, is necessarily opposite to the left hand of the object; so that no one ever sees himself in a single plane mirror as others see him or as a photograph shows him, but he sees all his features reversed.

Curved reflecting surfaces. In these we have to trace out the mode of reflection of incident rays from each "element" or little bit of the reflecting surface; and this leads, through geometrical working, to such propositions as the following: (1) Parallel rays travelling parallel to the axis of a concave paraboloid mirror are made to converge so as all actually to pass accurately through F, the geometrical *focus* of the paraboloid; and, conversely, if the source of light be at F, the rays reflected from the mirror emerge parallel to one another—a proposition of great utility in lighthouse work, search-lights, etc. (2) In spherical reflectors, which are those most easily made, there is no accurate focus except for rays proceeding from the center and returning to it. But practically spherical reflectors, whose size is small compared to the distance of the center of curvature, act approximately like parabolic reflectors for parallel rays. Practically rays parallel to the axis, that is, rays from a distant source of light, are reflected so as to pass through the principal focus. Concave mirrors act like convex lenses; convex mirrors like concave lenses. *(Standard Encyclopedia.)* See, also, **Angle of reflection,** p. 470 and p. 475, Vol. I; **Mirror,** p. 7842, Vol. X; **Reflected ray**; as well as **Diffusion of light,** p. 3967, Vol. V of this *Encyclopedia.*

Reflectors. These devices are described under **Reflection**; and **Mirror,** p. 7842, Vol. X of this *Encyclopedia.* A very good example is the so-called holophane reflector. See cut. It is of especial use for the illumination of test charts. The light source is screened from the object illuminated and from direct observation. There is, therefore, an absence of glare and of reflection from the illuminated surface. It should be frosted for uniform result, and, as more rays are utilized in effective illumination of a given area than is the case with any other method, maximum efficiency is obtainable only by these reflectors.

Reflectoscope. A form of reflective lantern.

Reflet. (F.) Having an iridescent lustre.

Reflex, Accommodation. Dilatation or contraction of the pupil in accommodation.

Reflex amblyopia. See **Amblyopia, Reflex,** p. 302, Vol. I of this *Encyclopedia.*

Reflex, Anomalous pupillary. Stimulation of the retina by light dilates the pupil.

Reflex-arc. A term applied to the combination of an afferent nerve, a nerve-center, an efferent nerve, and a muscle.

Reflex, Aschner. See **Oculocardiac reflex,** p. 8470, Vol. XI of this *Encyclopedia.*

Reflex, Attention. Alteration of size in the pupil when the attention is suddenly fixed.

Reflex, Babinski's. Extension of the toes instead of flexion on stimulating the sole of the foot; it occurs in lesions of the pyramidal tract, and indicates organic, as distinguished from hysteric, hemiplegia.

The Holophane Uniflux Reflector.

Reflex, Bechterew's. Dilatation of the pupil on exposures to light; sometimes seen in tabes and general paralysis.

Reflex, Choked. In skiascopy, absence of movement of the retinal illumination on reaching the point of reversal.

Reflex, Cilio-spinal. Dilation of the pupil on stimulation of the skin of the neck.

Reflex, Consensual. CROSSED REFLEX. See p. 4621, Vol. VI of this *Encyclopedia.*

Reflex, Corneal. EYELID CLOSURE REFLEX. Irritation of the conjunctiva closes the lids. See **Cornea, Reflex of the,** p. 3436, Vol. V of this *Encyclopedia.*

Reflex, Corneomandibular. Movement of the lower jaw toward the side opposite the eye whose cornea is lightly touched, the mouth being open.

Reflex, Cortex. Dilation of the pupil may be caused by electric and other stimulation of the cerebral cortex, especially of the occipital lobe. A similar effect has been produced by stimulation of the anterior four-fifths of the cortex.

Reflex, Crossed. Stimulation of one organ of one side of the body produces an effect on the other side. See **Reflex, Consensual.**

Reflex, Cutaneous pupillary. Dilatation of the pupil on pinching the skin of the cheek or neck.

Reflex, Davidson's. Illumination of the pupil when an electric light is held in the mouth.

Reflex, Direct light. See p. 4620, Vol. VI of this *Encyclopedia.*

Reflex, Eyeball-heart. See **Oculocardiac reflex.**

Reflex, Eyelid-closure. See **Gifford's reflex,** p. 4620, Vol. VI of this *Encyclopedia.*

Reflex, Foveal. The minute point of light, surrounded often by a halo, corresponding to the fovea centralis. See p. 5318, Vol. VII of this *Encyclopedia.*

Reflex, Gifford's. LID-CLOSURE REFLEX. PALPEBRAL PUPIL REFLEX. WESTPHAL-PILTZ REFLEX. Contraction of the pupil when an effort is made to close the lids while the latter are held apart. See p. 5384, Vol. VII; and p. 4620, Vol. VI of this *Encyclopedia;* also under **Pupil in health and disease.**

Reflex, Haab's. CEREBRAL CORTEX REFLEX. Bilateral pupillary contraction when the patient sits in a darkened room, and without accommodation or convergence directs his attention to a bright object already within the field of vision.

Reflexibility. REFLEXITY. The capacity for being reflected.

Reflex, Indirect. See **Reflex, Consensual.**

Reflex inhibition. An inhibition (e. g., of cardiac action) the result of a shock caused by an irritation or an injury to a peripheral tissue, which is carried to the brain, and thence is reflected by an efferent nerve to the inhibited organ.—(Foster.)

Reflex, Iris-contraction. See **Reflex, Direct.**

Reflex, Knee-jerk. PATELLAR REFLEX. WESTPHAL'S SIGN. Contraction or clonic spasm of the quadriceps muscle, produced by sharply striking the ligamentum patellæ when the leg hangs loosely flexed at right angles.

Reflex, Lid. LID-CLOSURE REFLEX. Same as *corneal reflex*. See p. 3436, Vol. V of this *Encyclopedia*.

Reflex, Light. A narrow, oval ring of light seen by means of the ophthalmoscope on the retina. It changes its shape according to the situation and characters of the illuminated spot.

Reflexes, Ocular. For a complete account of these see **Pupil**; as well as p. 9909, Vol. XIII, and p. 4620, Vol. VI of this *Encyclopedia*.

Reflex, Oculocardiac. ASCHNER REFLEX. A slowing of the rhythm of the heart following compression of the eyes. A slowing of from 5 to 13 beats per minute is normal; one of from 13 to 50 or more is exaggerated; one of from 1 to 5 is diminished. If ocular compression produces acceleration of the heart, the reflex is called *inverted*. See **Oculocardiac reflex**, p. 8470, Vol. XI of this *Encyclopedia*.

Reflex of the cornea. See **Cornea, Reflex of the**, p. 3437, Vol. V of this *Encyclopedia*.

Reflex, Pain (pupillary). See **Reflex, Sensory.**

Reflex, Palpebral. Simulators of profound deafness wink and the pupil contracts when an unexpected, loud noise is made outside the field of vision but close to the head.

Reflex, Palpebro-pupil. A name for Gifford's reflex.

Reflex, Paradoxic pupillary. Stimulation of the retina by light *dilates* the pupil.

Reflex, Patellar. See **Reflex, Knee-jerk.**

Reflex, Piltz's. See **Reflex, Gifford's.**

Reflex, Plantar. BABINSKI SIGN OR PHENOMENON. See **Plantar reflex,** p. 10252, Vol. XIII of this *Encyclopedia*.

Reflex, Psychic. See **Psychic reflex.**

Reflexes, Pupillary. See **Pupil,** and p. 4620, Vol. VI of this *Encyclopedia*.

Reflex, Red. In skiascopy and ophthalmoscopy the pupillary field shows the red reflection from the fundus. For an explanation of this phenomenon, see p. 8939, Vol. XII of this *Encyclopedia*.

Reflex, Relaxed accommodation. Dilation of the pupil in looking from a near to a distant point or object.

Reflex, Senile. A gray reflection from the pupil of aged people due to hardening of the lens.

Reflex, Sensory. PAIN REACTION OF THE PUPIL. Same as skin-pupillary reflex; also, when the faradic current is applied to the nape of the neck dilation of the pupil occurs. The same result is obtained in certain susceptible subjects on tickling the soles of the feet, the palms of the hands, or other sensitive parts of the body. Dilated pupils are also noticed in persons affected by sudden joy, anger, grief or any other violent passion; in which instances the origin of the dilatation is in the cerebral centers. See p. 3603, Vol. V of this *Encyclopedia,* also **Pupil.**

Reflex, Shot-silk. See **Reflex, Watered-silk.**

Reflex, Skin-pupillary. SKIN REFLEX. CUTANEOUS STIMULATION TEST. Dilatation of the pupil produced by irritation of the skin of the neck. See p. 3603, Vol. V of this *Encyclopedia.*

Reflex, Watered-silk. A peculiar appearance, like that of watered silk, visible especially upon the retinas of children; also called *shot-silk retina.*

Reflex, Weiss'. A curved reflex seen with the ophthalmoscope on the fundus of certain eyes, to the nasal side of the disk; believed to be indicative of myopia.

Reflex, Westphal-Piltz. See **Reflex, Gifford's**; also **Pupil in health and disease.**

Reflex, Westphal's pupillary. Contraction of the pupil associated with closure or attempted closure of the eye. See **Pupil.**

Reflex, Winking. See **Cornea, Reflex of the,** p. 3437, Vol. V of this *Encyclopedia.*

Reform eye. See p. 623, Vol. I and p. 10398, Vol. XIII of this *Encyclopedia.*

Refract. To bend or turn from the direct course; to deflect a ray. Sometimes, though improperly, used to designate the act of measuring or determining the ocular refraction, e. g., "he refracted the patient" instead of "he measured the patient's refraction" or "found the refraction of the patient to be."

Refractable. REFRANGIBLE. Capable of being refracted.

Refracted ray. In *optics,* a ray of light whose direction, either within or on emergence from a transparent medium, is the result of refraction.—(C. F. P.)

Refracting angle. The angle between the refracting surfaces of a prism; the apical angle. See also **Angle.**

Refracting dial. A form of sun dial, having a glass lens in place of a gnomon.

Refracting media. The cornea, aqueous humor, crystalline lens and vitreous humor.

Refracting surface. The surface which separates two transparent media, and to which the change in the direction of a ray of light is due.

Refracting telescope. A telescope transmitting the rays to a focus through a combination of lenses.

Refraction and accommodation of the eye. In *physics*, refraction means the bending or change of direction of a ray of light as it passes from one medium into another of different density. This may be single or double, the latter when the ray is separated into two rays, a property [double refraction (q. v.)] possessed by certain crystals such as *calcite,* etc. The laws of refraction explain various cosmic phenomena and the action of lenses, prisms, and optical instruments generally. See also **Achromatism,** p. 60, Vol. I; **Decomposition of light,** p. 3793, Vol. V; **Diffraction,** p. 3965, Vol. V; **Dispersion of light,** p. 4039, Vol. VI; **Focus,** p. 5236, Vol. VII; **Index of refraction,** p. 6186, Vol. VIII; **Law of refraction,** p. 7024, Vol. IX; **Lens,** p. 7191, Vol. X, etc., of this *Encyclopedia.*—(C. F. P.)

In this *Encyclopedia human refraction and its errors* in most of their complex relations have been to some extent discussed. The reader is referred in this connection to the section on **Physiological optics,** especially to chapter vi, p. 9805; to chapter x, p. 9849; and to chapter xiv, p. 9916, Vol. XIII; and by no means overlooking most of the section **Lenses and prisms,** p. 7233, Vol. X. Portions of the subject are also treated in a practical manner under the heading **Examination of the eye,** on pp. 4718 and 4762, Vol. VI, and p. 3987, Vol. V; as well as under **Dioptrics,** p. 3987, Vol. V; also under **Skiascopy** and **Ophthalmoscopy** (p. 9020, Vol. XII). See, also, **Emmetropia,** p. 4299, Vol. VI; **Ametropia,** p. 310, Vol. I; **Myopia,** p. 8265, Vol. XI; **Astigmatism,** p. 656, Vol. I; **Oblique astigmatism,** p. 8412, Vol. XI; **Hypermetropia,** p. 6096, Vol. VIII of this *Encyclopedia.*

The *refraction and accommodation of lower animal eyes* are also discussed under **Comparative ophthalmology,** p. 2519, Vol. IV.

The *accommodation of the eye* has already been discussed on p. 48, Vol. I, and following rubrics, of this *Encyclopedia.* See, also, **Presbyopia,** p. 10357, Vol. XIII; and paragraphs 66-70, under **Physiological optics,** p. 9806, Vol. XIII.

Consult, also, **Eyestrain,** p. 5126, Vol. VII of this *Encyclopedia.*

PART I. INTRODUCTORY PRINCIPLES AND METHODS OF HUMAN REFRACTION.

Owing to the length and importance of this section an index of chapter headings has been prepared for the convenience of the reader.

PART I. INTRODUCTORY. CHAPTER I. DIOPTRICS—CARDINAL POINTS—SCHEMATIC EYE—DIOPTRIC SYSTEM AND THE RETINA—EMMETROPIA—HYPERMETROPIA—MYOPIA—ASTIGMATISM—VARIOUS FORMS OF ASTIGMIA—

SOUTER'S OPHTHALMOPHAKOMETER. CHAPTER II. ACCOMMODATION OF THE EYE—HISTORICAL—THEORIES OF ACCOMMODATION—MECHANISM OF ACCOMMODATION—RANGE OF ACCOMMODATION—TSCHERNING'S THEORY. CHAPTER III. CONVERGENCE—METRE ANGLE—RANGE AND AMPLITUDE OF CONVERGENCE—RELATION BETWEEN ACCOMMODATION AND CONVERGENCE—ANGLES ALPHA AND GAMMA—OCULAR LINES AND POINTS. CHAPTER IV. PRESBYOPIA—EFFECT OF AGE AND REFRACTION ON PRESBYOPIA—RULES FOR PRESCRIBING GLASSES IN PRESBYOPIA—ANISOMETROPIA AND ANTIMETROPIA—APHAKIA—CORRECTION OF REFRACTIVE ERRORS IN APHAKIA. CHAPTER V. THE VARIOUS FORMS OF AMETROPIA AND THE SYMPTOMS THEY CAUSE—MANIFEST AND LATENT HYPERMETROPIA—CLINICAL ASPECTS OF MYOPIA—GENERAL DIRECTIONS FOR CORRECTING THESE REFRACTIVE ERRORS. CHAPTER VI. SOME CLINICAL ASPECTS OF ASTIGMATISM—THE FORMS OF ASTIGMATISM—REGULAR AND IRREGULAR ASTIGMIA—ASTIGMATISM WITH AND AGAINST THE RULE—AXES OF ASTIGMATISM. CHAPTER VII. APPLIED REFRACTION—THE USE OF CYCLOPLEGICS AND MYDRIATICS—THE DIFFERENT METHODS OF MEASURING REFRACTION—TESTS FOR THE ACUTENESS OF VISION—TEST LETTERS AND CHARTS. CHAPTER VIII. THE USE OF THE OPHTHALMOSCOPE—THE DIRECT METHOD—THE INDIRECT METHOD—THE FUNDUS APPEARANCES IN AMETROPIA—RETINOSCOPY OR SKIASCOPY—THE OPHTHALMOMETER AND ITS EMPLOYMENT IN MEASURING THE CORNEAL ASTIGMATISM.

PART II. CLINICAL APPLICATIONS OF REFRACTIVE METHODS. CHAPTER IX. SIMPLE HYPERMETROPIA AND HYPERMETROPIC ASTIGMATISM WITH AND AGAINST THE RULE—ILLUSTRATIVE CASES—PRESCRIPTIONS FOR GLASSES AND THE FORMULÆ OF LENSES—COMPOUND HYPEROPIC ASTIGMIA WITH AND AGAINST THE RULE—CASES IN ILLUSTRATION. CHAPTER X. SPASM OF ACCOMMODATION IN REFRACTION WORK AND HOW TO DEAL WITH IT—TONICS, OCULAR REST AND CYCLOPLEGICS—CASES ILLUSTRATING ACCOMMODATIVE SPASM AND ITS TREATMENT. CHAPTER XI. MEASUREMENT OF MYOPIA—SIMPLE MYOPIC ASTIGMATISM—SPASMODIC OR FALSE MYOPIA—RULES FOR PRESCRIBING NEAR OR READING GLASSES IN HIGH DEGREES OF MYOPIA—PROGRESSIVE AND MALIGNANT MYOPIA AND THEIR TREATMENT—PRESBYOPIA AND THE TRANSPOSITION OF GLASSES FROM DISTANCE TO READING FORMULÆ IN MYOPES. CHAPTER XII. CORRECTION OF COMPOUND MYOPIC ASTIGMATISM—THE USE OF THE OPHTHALMOMETER IN MYOPIC ASTIGMIA—ILLUSTRATIVE CASES WITH EXPLANATORY DIAGRAMS. CHAPTER XIII. THE CORRECTION OF ANISOMETROPIA AND ANTIMETROPIA—ILLUSTRATIVE CASES—TRANSPOSING FORMULÆ—CHOICE OF LENSES IN OPPOSED AMETROPIA. CHAP-

TER XIV. MIXED ASTIGMATISM—ILLUSTRATIVE CASES. CHAPTER XV. ASTIGMATISM AFTER CATARACT EXTRACTION—ILLUSTRATIVE CASES. CHAPTER XVI. REFRACTION AND ACCOMMODATION IN IRREGULAR ASTIGMATISM—CONICAL CORNEA—ILLUSTRATIVE CASES. CHAPTER XVII. EXCEPTIONAL CASES OF REFRACTION. CHAPTER XVIII. CASES EXHIBITING DIFFERENCES BETWEEN OPHTHALMOMETRIC MEASUREMENTS AND SUBJECTIVE FINDINGS.

INTRODUCTORY.

CHAPTER I.

DIOPTRICS. THE DIOPTRIC SYSTEM AND THE RETINA. EMMETROPIA, HYPERMETROPIA, MYOPIA AND ASTIGMIA.

For a correct understanding of the practical side of the refraction and accommodation of the eye, a knowledge of the *general principles of optics,* and of *physiologic optics* (q. v.) is necessary. However, since these two theoretical branches of the subject are fully treated in another portion of this *Encyclopedia,* the writer will limit himself in the main to a consideration of *practical optics* and to applied refraction.

The human eye may be regarded as a miniature camera, and when we speak of the *refraction of the eye,* we have in mind the dioptric or refractive power of the optical apparatus of the eye when it is in a *state of rest,* which is known as the *static refraction of the eye.* When the accommodation is brought into play, it is spoken of as the *dynamic refraction* of the eye. The second condition, or *dynamic* refraction, we shall consider under the *accommodation* of the eye, and hereafter, when discussing refraction, only the *static* refraction, or the eye in a state of rest, will be taken into account.

The dioptric or refractive apparatus of the eye is composed of the cornea, the lens, the aqueous and vitreous, which, taken in their entirety, may be considered a compound lens. This compound lens has three refractive surfaces, the anterior surface of the cornea, the anterior surface of the lens, and the posterior surface of the lens, their combined effect having the power of a convex lens of about 23 millimeters focus, or the depth of the emmetropic eye. In a state of rest, therefore, images produced by this compound lens are distinctly focused on the retina or receiving plate of an emmetropic eye (providing, of course, that the media are clear); and the stimulation of the retina by the rays of light forming these images and the transmission of this stimulus by the optic nerve fibres to the cortex of the brain result in the conscious sensation of vision, or sight, as perceived by the individual.

Although the eye has been compared to a camera, the comparison does not hold true or exact in every particular. In the first place, the camera has a single lens with two positive refracting surfaces, while the human eye has a positive refracting surface at the anterior surface of the cornea, and the biconvex crystalline lens; the posterior surface of the lens resting in a concave or cup-shaped portion of the vitreous, which latter medium, owing to its concave front surface, has a dispersing effect on rays of light entering it.

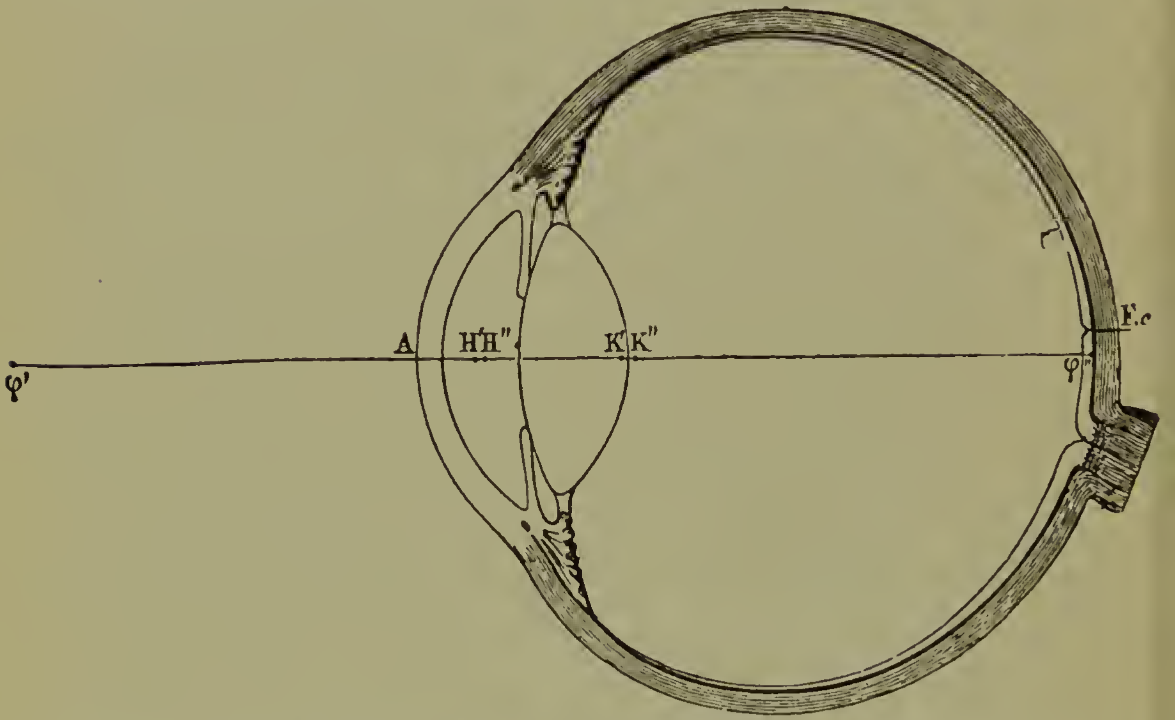


Fig. 1. Schematic Eye, Three Times Natural Size. ø' anterior or first principal focus; A, anterior surface of the cornea; H' and H" principal points; K' and K", nodal points; ø", posterior or second principal focus; Fc, *fovea centralis;* ø'ø", optic axis.—(After Landolt.)

Again, in the camera rays of light proceed from a rarer medium, pass through a denser one, the convex lens, and re-enter the rarer medium, the air; whereas, with the eye, while the rays of light proceed from a rarer medium, the air, and pass through a denser one, the cornea, aqueous and lens, they finally re-enter a denser medium than air, the vitreous. The retina, of course, plays no part in the formation of the images, serving only as a sensitive screen or plate upon which the images are formed by the dioptric or refracting apparatus of the eye.

While the reader is referred to the section on **Physiologic optics** for a detailed and comprehensive description of the dioptric apparatus of the eye, of its anatomy, physiology, functions, etc., a reproduction hereof the schematic eye with a brief description of its *cardinal points* is desirable for a clearer understanding of the clinical portion of the subject. The schematic eye, which may be taken to represent the emmetropic eye in the living subject, is depicted, with the *six cardinal points* present in the compound lens system. See, also, **Schematic eye.**

The six cardinal points of the eye are *the two principal points, the two nodal points,* and *the two principal foci.* These points are determined after the method of locating similar points when following the direction of rays of light through a single lens or spherical surface which separate media of different refractive indices. For example, first, in a single refracting lens or surface, the point on the principal axis at which it intersects the refracting surface is called the *principal point,* and if we pass a line through this point at right angles to the principal axis, we call this the *principal plane;* second, the point at the center of curvature of the refracting surface, through which all straight lines from an object must pass to corresponding points of the image, is called the *nodal point;* third, that point in front of the refracting surface from which rays emerge and become parallel to the principal axis after passing through the refracting lens or surface, is called the *first principal focus,* and a line drawn through this focus at right angles to the principal axis is called the *first principal focal plane;* fourth, the point on the principal axis at which rays of light parallel to each other and the principal axis, before entering the refracting lens or surface, are brought to a focus, is called the *second principal focus,* and a line drawn through this point at right angles to the principal axis is *the second principal focal plane.*

In the dioptric system of the eye, all of the cardinal points are situated on the optic axis. These are six in number. In other words, besides the two principal foci, there are *two* principal points and *two* nodal points, due to the combined action of the cornea and the crystalline lens.

In the eye, the *two principal points* are situated in the anterior chamber slightly back of the cornea (H′ and H″, Fig. 1.) When an incident ray passes through the first principal point, the corresponding emergent ray must pass through the second principal point; however, the emergent ray does not proceed in a parallel direction with the incident ray. In the lens system of the eye these two points are so close together that they are considered as but one.

The principal points are images, one of the other. A line drawn through the first principal point at right angles to the optic axis is called the first principal plane, and a similar line drawn through the second principal point is called the second principal plane. These planes are reciprocally the image, one of the other. Furthermore, these images are of the same size and located on the same side of the principal axis, since the incident rays which enter the first principal plane emerge from the second principal plane at the same distance from the principal axis and on the same side of it. This holds true only as regards the principal points and not for the nodal points or the two principal foci.

The two nodal points of the eye are situated near the posterior surface of the lens, and at the optic center of the refracting system of the eye (K′ and K″, Fig. 1). Every incident ray of light directed towards the first nodal point, after it is refracted, seems to come from the second point, and the emergent ray continues in a parallel direction with the incident ray. The nodal points are reciprocal images one of the other, and these points are separated by the same distance as are the two principal points. The two principal points and also the two nodal points are so near together that each pair may be regarded as but a single point. The axis rays passing through the nodal point are not refracted and are termed lines of direction.

The two principal foci are situated on the optic axis, one in front, the other back of the refracting system. *The first principal focus* is situated on the optic axis at that point from which incident rays become parallel to the optic axis after entering the eye, or vice versa, where parallel rays of light in the eye come to focus in front of the eye. (Ø′ Fig. 1.)

The *second principal focus* is at that point on the optic axis of the eye, where incident rays parallel to the optic axis before entering the eye, become focused in the eye. (Ø″, Fig. 1.)

Lines drawn through the principal foci at right angles to the optic axis are called the focal planes. Rays from any point on the first focal plane, after refraction, are rendered parallel to the ray of direction and to each other; and parallel rays, after refraction, are brought to a point or focus in the second focal plane.

The first principal focal distance is the distance between the first principal focus and the first principal point, while the second principal focal distance is the space between the second principal focus and the second principal point. (See Fig. 1.)

Helmholtz gives as the average dimensions of the dioptric system of the eye the following figures, cited by Landolt (*Refraction and Accommodation of the Eye,* page 120) which are herewith reproduced:

Index of refraction of the cornea, aqueous humor, and vitreous body, 1.3365.

Total index of refraction of the crystalline lens, 1.4371.

Radius of curvature of the cornea, 7.829 millimetres.

Radius of curvature of the anterior surface of the crystalline lens, 10.0 millimetres.

Radius of curvature of the posterior surface of the crystalline lens, 6.0 millimetres.

Distance from the apex of the cornea to the anterior surface of the crystalline lens, 3.6 millimetres.

Distance from the apex of the cornea to the posterior surface of the crystalline lens, 7.2 millimetres.

Thickness of the lens, 3.6 millimetres.

The dioptric system and the retina. Keeping in mind the cardinal points of the eye (the two principal and the two nodal points, each pair being considered as but one point), we will consider briefly the method of formation of images on the retina. As is well known, all images are formed on the retina in an inverted position relative to the object. For example, in Fig. 2 AB is formed on the retina in an inverted position ba. The line of direction from A of the object, above the optic axis, goes through the nodal point C and strikes the retina at A below the optic axis; likewise all points of the object above the optic axis send rays through the nodal point C to corresponding points on the retina below the optic axis. On the other hand, rays of light from B below the optic axis, after passing through the nodal point strike the retina at B above the optic axis, and all points of the object below the optic axis send rays through the nodal point to corresponding points on the retina above the op-

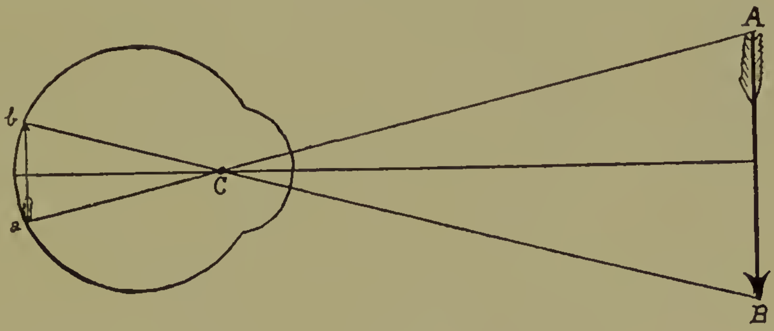


Fig. 2. Showing Formation of Images on the Retina.

tic axis. Hence a complete inverted image, ba, is formed on the retina. The mind learns to interpret this image, however, as upright. From a photographic point of view, and especially as applied to the eye, the inverted image has a great advantage over the erect image, because, by having the rays of light cross at the nodal point (in so doing they can pass through a very small opening, the pupil), and, diverging from there on to the retina, or receiving plate of the camera, the image is much larger than it would be possible to have it if the rays did not cross, but continued straight onward to meet first at the retina and form an erect image. In the latter instance, rays passing through so small an opening as the pupil could form but a relatively small image. See **Inversion of the image,** p. 6560, Vol. IX of this *Encyclopedia.*

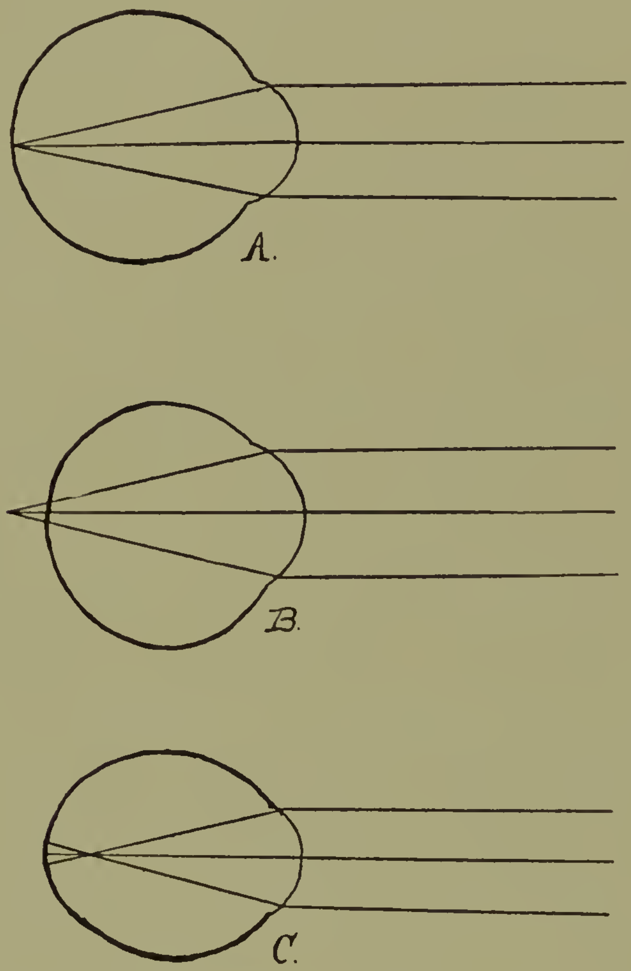


Fig 3. A.– EMMETROPIA.
B. – HYPERMETROPIA,
C. – MYOPIA.

Emmetropia, hypermetropia, myopia. When the dioptric system of the eye, in a state of rest, brings parallel incident rays to an exact focus on the retina, we term that condition *emmetropia,* and the eye *emmetropic:* when such are brought to a focus back of the retina, we call that condition *hypermetropia,* and the eye *hypermetropic:* when such rays are brought to a focus in front of the retina, that condition is known as *myopia,* and the eye *myopic.*

Astigmia. The refractive surfaces of the dioptric system of the eye may be so shaped that some of the rays of light entering the eye may focus on the retina, while other rays from the same object may focus back of the retina *(hypermetropic astigmatism);* or, all of the light rays may focus back of the retina, but some farther back than others *(compound hypermetropic astigmatism);* or, some of the rays may focus on the retina while others focus in front of it *(myopic astigmatism);* or all of the rays may focus in front of the retina, but some farther forward than the others *(compound myopic astigmatism);* or some of the rays may focus in front of the retina while some focus back of it *(mixed astigmatism).* Such conditions are called *astigmatism,* or *astigmia,* and the eye astigmatic. In such conditions the rays of light are not brought to a clear focus or point, but are drawn out more or less into a line, a circle, or oval. All refractive conditions of the eye other than that of *emmetropia,* are classed under the term *ametropia,* which term includes hypermetropia, myopia, astigmia.

Hypermetropia.

Hypermetropia may be due, theoretically, to any of the following conditions (Parsons, *Pathology of the Eye,* page 932, Vol. 3):

(A) Abnormal shortness of the eye—*axial hypermetropia.* (B) Abnormal curvature of the refractive surfaces—*curvature hypermetropia:* (a) too slight curvature of the cornea; (b) too slight curvature of one or both surfaces of the lens. (C) Abnormal refractive index of the media—*index hypermetropia:* (a) too low index of the cornea or aqueous; (b) too low index of the lens due to (1) too low index of the nucleus; (2) too high index of the cortex; (3) both these causes. (D) Too high index of the vitreous. (E) Abnormal position of the lens—i. e., displacement backwards. (F) Absence of the lens. (G) A combination of the above abnormalities.

Axial hypermetropia is the one we have to deal with, clinically, in the vast majority of cases. The hypermetropic eye is not only shorter in the optic axis, but, as a rule, is smaller in all diameters than the emmetropic and myopic eye; the corneal diameter is frequently reduced, and the anterior chamber shallower than in either the emmetropic or myopic eye. These are not pathologic defects, however, but are normal relative to the decrease in the size of the eye. That the structure of the hypermetropic eye is not prone to produce pathologic changes is evidenced by the fact that it seldom presents the structural and mechanical changes seen in myopic eyes. It is true that occasionally we may observe posterior sclerochoroidal ectasiæ, and the crescent at the disc, of a moderate degree, but usually so small in extent as not to affect the visual acuity. These changes in the hypermetropic eye are brought about in exactly the same manner as like changes in myopic eyes, that is, by a lengthening of the eyeball, which takes place when the flat, hypermetropic eye approaches in length toward emmetropia and myopia. As is well known, most human beings are born with hypermetropic eyes, and the tendency is always towards the lengthening of the optic axis, that is, towards myopia. In this lengthening process usually no change takes place in the membranes of the eye until the myopic stage of refraction has been reached. Hence the relative infrequency of changes observed in the hypermetropic eye as compared with the myopic eye.

There is frequently to be observed in the hypermetropic eye a peculiar condition which is termed "watered silk," or "shot silk" from its supposed resemblance to the sheen of silk. It is a physiologic state. Again, in the hypermetropic eye a condition is frequently observed that resembles neuritis. The disc may be somewhat swollen and the outlines, especially on the nasal side, obscured. The finer blood vessels are increased in number and striæ or white lines are prominent along the larger vessels. The condition has been termed "pseudoneuritis (Stephenson) or hyperopic disc." As it is not progressive, and the vision not affected, a few weeks of observation, by anyone in doubt as to its real nature, serves to clear up the diagnosis. See, e. g., **Neuritis, Spurious,** p. 8329, Vol. XI of this *Encyclopedia.*

The other forms of hypermetropia other than the axial, as *curvature* and *index* hypermetropia, and hypermetropia due to luxation, displacement or absence of the crystalline lens (if we except the cases of absence of the opaque lens following cataract operation), comprise but a relatively small per cent. of all cases of hypermetropia.

Curvature hypermetropia may be placed in the *pathologic class,* since it has been demonstrated by numerous observers that in the normal eye there is no *definite relation* between the radius of curvature of the cornea and the refractive condition of the eye, either in hypermetropia or myopia. Donders called attention to this point long ago. (See citation under *Myopia.*)

Index hypermetropia is a rare condition, sometimes observed in diabetic subjects, and is usually of a transitory nature. It may be accounted for either by an increase in the refractive index of the vitreous or of the cortical layers of the crystalline lens. The hypermetropia of the aged may also be accounted for by an increase of the refractive index either of the vitreous or of the cortical layers of the lens, or perhaps to a weakened condition of the ciliary muscle.

Hypermetropia due to luxation of the lens is usually of a pathologic nature. Hypermetropia brought about by removal of the crystalline lens in a previously emmetropic eye, amounts to about ten or eleven diopters.

Myopia.

According to the classification of Parsons, myopia may be due, theoretically, to any of the following conditions: A. Abnormal length of the eye—*axial myopia.* B. Abnormal curvature of the refracting surfaces—*curvature myopia:* (a) too strong curvature of the cornea; (b) too strong curvature of one or both surfaces of the lens. C. Abnormal refractive index of the media—*index myopia:* (a) too high index of the cornea or aqueous; (b) too high total index of the lens, due to (1) too high index of the nucleus; (2) too low index of the cortex; (3) both these causes. (c) Too low index of the vitreous. D. Abnormal position of the lens—i. e., displacement forwards. E. A combination of the above abnormalities.

Axial myopia. Of the different forms of myopia, the axial variety, where the antero-posterior diameter of the eye is too long, is the one with which we have to deal in the vast majority of cases. Clinically, it may be divided into three classes of cases which Donders termed *stationary, temporarily progressive,* and *permanently progressive,* which latter is often designated *malignant myopia.*

The so-called *stationary* form of myopia increases but a very little in amount, not above three or four diopters as a rule, and there are no pathologic changes, at least none due to the structure of the eye.

Temporarily progressive myopia increases slowly, and rarely exceeds eight diopters in amount. Donders claims that the increase lies mostly between the 12th and 25th years of age, and further that it is exceptional, after having attained to as much as 8 diopters, for it to remain entirely stationary. Experience has brought out the truth of the above observations.

Permanently progressive myopia may be of rather high degree, even in the young, and is not confined to the educated classes, often being observed in the uneducated. It develops most rapidly up to the 25th year, then, as a rule, more slowly, but does not cease to increase even in advanced age. Diminution in such degrees of myopia (15 to 20 D.) at an advanced time of life is not to be thought of; the influence of the increasing distension of the eye in the direction of the visual axis is never overcome, and is even not compensated for by the diminishing refraction of the lens.

Structural changes in myopia. These are confined almost wholly to the posterior segment of the eye, the optic disc, sclera, choroid and retina being involved, the posterior pole and macular region being especially prone to changes in the higher degrees of myopia.

One of the earliest and most commonly observed changes in the myopic eye, even of low degree, is the *myopic crescent.* This is usually seen to the outer or temporal side of the disc, though it may occupy any position around the border of the disc. As its name implies it is crescentic in shape, varying in width at its widest part, from a narrow band to ⅓ the diameter of the optic disc itself, and usually extends ⅓ to ½ way around the disc. Its borders may be sharply cut and smooth, often, however, the outer edge or border farthest from the disc is irregular in outline and pigmented. With increase of the myopia the crescent usually broadens, until it may be twice the diameter of the disc, and may also completely encircle it. With increase in width, the surface of the crescent may become sunken, thus forming a true staphyloma. And as this depression progresses both in width and depth, due to thinning and stretching of the sclerotic coat, a true *ectasia* or *posterior staphyloma* is formed. The choroid and retina are thinned and stretched at the same time, and when the staphyloma extends to the posterior pole and the macula becomes involved, the vision is markedly reduced. This depression of the sclera may be observed with the ophthalmoscope and its outline and depth estimated. Peculiar to this condiiton in some cases of high myopia are also dark, crescentic lines or shadows at the border of the staphyloma, which are crescentic with the optic disc, but more pronounced as a rule on the nasal side of the disc. The retinal vessels when passing over them make a marked turn and may even be lost to sight, as observed in cupping of the disc in glaucoma. Furthermore, the surface of this depressed portion of the fundus is paler than the surrounding parts, due to stretching of the choroid and retina and thinning of the pigment, the choroidal vessels often showing through.

As to the cause of posterior staphyloma, Graefe was of the opinion that it was to a low grade inflammation of the sclera and choroid at the posterior pole of the eye, which he designated by the term "sclerotico-choroiditis posterior." The inflammatory origin of the trouble was questioned by later observers, and Graefe himself yielded from his first position. By the majority of surgeons the condition is thought to be brought about by stretching and thinning of the sclera with atrophic changes in the choroid and deeper layers of the retina. See, also, **Conus,** p. 3286, Vol. V of this *Encyclopedia.*

Excessive traction on the retina. In this condition the retina is stretched or dragged over the nasal side of the disc (Jaeger); and in some cases of high myopia Nagel states that the displacement of the retina may reach very near to the center of the disc. Microscopic examinations of such cases show that not only the retina is displaced, but that the choroid also is dragged onto the nasal half of the disc, though not to the same extent as the retina. At the same time the temporal border of the optic disc may be dragged or pushed out over the border of the sclera (Weiss). Weiss has also called attention to a reflex streak, crescentic in shape, at the nasal margin of the disc which often is to be seen in beginning myopia. The condition is due, he states, to a slight detachment of the vitreous at this point, with a fluid exudate beneath.

Detachment of the retina itself occurs in about one or two per cent. of all cases of myopia, taking place relatively more frequently in the higher grades of myopia. Even a rent in the retina may be observed at times. Rarefaction and partial absorption of the pigment layer, together with degenerative changes in the posterior layers of the retina, are of common occurrence in the higher degrees of myopia. These changes in the retina, Parsons states, "are wholly secondary to those in the choroid," and are limited at first to the outer layers, which are dependent upon the chorio-capillary layer of the choroid for their nutrition. However, at the macular region, the degenerative changes may affect the entire thickness of the retina, while the pigment and even the pigment cells in certain areas of the retina may become partly absorbed and in other portions the pigment may be piled in heaps. The *macular region* is especially subject to these changes both in the retinal and choroidal layers. The atrophic spots may be whitish or yellowish-white in color; again the spots may be pigmented and irregular in shape, and may be so extensive as to reach to the disc. Whitish branched lines may occupy this region, and small hemorrhages sometimes occur.

Occasionally, in high myopia, dense, almost circular pigment spots may be seen in the macular region, and are known as Fuchs' pigment spots. Förster first called attention to them, as long ago as 1862. According to the investigations of Lehruns they are due to a heaping up of the retinal pigment.

The vertical oval appearance of the optic disc itself in high myopia, as viewed with the ophthalmoscope (excluding the effect an astigmatic refraction might produce), may be due to a slight oblique position of the nerve head, brought about by displacement of the disc to the temporal side (Weiss, Heine). Perhaps also a slight retraction of the temporal half of the disc may have some influence to produce this effect.

The ciliary muscle in myopia, especially in the higher grades, is less well developed than in emmetropia or hypermetropia, simply from the want of exercise, the circular fibres of the muscles in particular being affected. Other distinguishing features of the myopic eye, as contrasted with emmetropic and hypermetropic, are: a deeper anterior chamber, vitreous opacities, and in the higher degrees a prominent appearance, due to elongation of the eyeball. Furthermore, in these higher degrees, the cornea is sometimes flatter or less round than in emmetropia, contrary to what is frequently assumed to be the case, that is, in axial myopia that the radius of curvature of the cornea is shorter than in emmetropia. Conical cornea and diseased conditions of the cornea are not here considered.

Causes of myopia.

The etiology of myopia has been widely discussed, and while the various factors that may enter into its causation have not been fully agreed upon, the main or underlying ones have received general recognition. Broadly speaking, the causes may be divided into two classes: (1) influences external to the eyeball; and (2) influences in the tissues of the eyeball itself.

External influences: (1) *Heredity*—According to Hirschberg (*Treatment of Shortsight,* page 109, 1912) and many other observers, heredity plays an important part in the production of myopia, a point of view shared by most surgeons to-day, and this, in spite of the fact, as proved by statistics, that most children are born hypermetropic or emmetropic. Nevertheless, the tendency to myopic refraction is more pronounced in those children born of myopic than in those born of hypermetropic parents, the condition tending to run in certain families. In other words, the eyes of children born of myopic ancestors though emmetropic or hyperopic at birth, when subjected to the same strain as the eyes of children born of hyperopic parents, yield more readily to the strain, and apparently so only because of an inherent weakness.

That most if not quite all children are born with hyperopic or emmetropic eyes has been abundantly proved. H. Cohn (*Untersuchung der Augen von 10000 Schulkindern.* Leipzig, 1867). Herrnheiser, Roosa and Ely (*Archives of Ophthalm.,* Vol. IX, No. 1, p. 29), and many others, have furnished statistics on the subject. Although very few, if any, children are born myopic, this condition of the refraction begins to manifest itself early in life, about the seventh or eighth year, rarely before this, and increases rapidly in the number of cases affected up to the 20th year. The degree of the myopia also increases more or less rapidly, according to occupation, up to 20 years of age, when, as a rule, it ceases to increase. Cases which continue to progress more or less rapidly beyond this age usually show pathologic changes and are termed *malignant* myopia, which is really a diseased condition of the eye not dependent upon occupation. However, it may be made worse by abuse or overuse of the eye under unhygienic surroundings. In fact, it is claimed that the ordinary forms of myopia (mildly progressive) may be changed into the true progressive or malignant myopia, by overuse of the eye under unsuitable conditions, as in bad light, in the recumbent position, long hours without rest, and when the general health is run down.

(2) *Shape of the orbit.* To the conformation of the orbit has been attributed an influence on the shape of the eyeball. Stilling asserts that in orbits with low roofs or short vertical diameters, the superior oblique muscle, owing to the low position of the attachment of the trochlea exerts greater pressure on the eyeball than in orbits with a greater vertical diameter. This increased pressure of the superior oblique muscle on the equator of the eyeball is supposed to cause elongation of the eye in its antero-posterior axis. Hamberger, Schmidt-Rimpler, Herrnheiser and others who have made measurements of orbits to ascertain if a fixed relation between the size of the orbit and the length of the eye obtained, failed to find any such relation, and rejected Stillings' theory.

(3) Even the *shape of the head* has been invoked to account for myopia. Broad heads with wide inter-pupillary distances are supposed to exert a predisposing influence on the development of the long or myopic eye, e. g., as follows: With a wide pupillary distance, the

eyes, in order to fix an object especially near at hand, are forced to turn farther inward than when the pupillary distance is narrow. In so doing, the external recti muscles are forcibly stretched over the temporal halves of the globe, which pressure on the side of the eye tends to elongate it in the antero-posterior diameter, the sclera stretching and extending backwards.

(4) The influence of *occupation*, especially any occupation requiring *near work*, as in school work, sewing, etc., has, for a long time, been recognized as a cause of myopia, that is, of the benign or non-malignant type. It may be a factor also in making worse the progressive form, which is not due to occupation, but to the tendency which is supposed to be inherited. That near work, reading, studying, etc., may produce myopia is evidenced by the frequency that myopia is observed in school children, and the higher the grade the more frequent the affection and the higher the degree of the myopia. From about the age of seven or eight up to twelve or fourteen years is the period myopia is most apt to manifest itself, and it is very liable to increase more or less rapidly until twenty years of age, when usually its progress is arrested. The posterior segment of the eye gradually extends backwards, with no or but little pathologic change in the membranes, the antero-posterior axis of the eye being lengthened, thus bringing about true *axial* myopia.

Just how near work brings about lengthening of the eyeball has been the subject of discussion. Donders (*Accommodation and Refraction of the Eye*, p. 343) states that three factors enter into its causation; "(1) Pressure of the muscles on the eyeball in strong convergence of the visual axes; (2) increased pressure of the fluids, resulting from accumulation of blood in the eyes in the stooping position; (3) congestive processes in the fundus oculi, which, leading to softening, even in the normal, but still more under the increased pressure of the fluids of the eye, give rise to extension of the membranes."

The second factor, as given by Donders, the *stooping position*, which causes congestion in the fundus, is now generally conceded to be a potent one in the causation of myopia. And the *recumbent* position, as when lying in bed, reading, should be placed in the same category of causes as the stooping position.

The third factor, congestive processes in the fundus which lead to softening, has been accepted by some surgeons and rejected by others. Von Graefe (cited above) put forth the theory that a true inflammatory process in the choroid and sclera, followed by thinning and stretching of these membranes, was the cause of posterior staphyloma, in high myopia. At present this theory is rejected almost wholly, as evidences of such posterior inflammatory processes in these cases have seldom been found.

(5) The influence of *excessively active accommodation* as a factor in the production of myopia may be eliminated from the discussion, though it has had very eminent supporters, among others Tscherning (*Physiologic Optics,* p. 87), who also cites Javal in its support. The theory of Horner, that a short optic nerve may produce myopia by traction on the posterior segment of the eye in its various movements, may also be eliminated as improbable. Neither claim has been sufficiently substantiated by facts.

(6) *Sex* plays a relatively unimportant part in the causation of myopia, though statistics would seem to show that, especially in the higher degrees, it is more frequently observed in women than in men. That *race* plays a part in the production of myopia is doubtful, although the Jewish race is supposed to be more frequently afflicted with the higher degrees, and especially of the malignant type, than other races.

Parsons (*Pathology of the Eye,* Vol. 3, p. 926), after carefully reviewing the literature on the subject of myopia, and its causes, states that: "The evidence in the matter of the extrinsic theories of myopia is therefore discordant and unsatisfactory. More weight must be attached to what may be called the intrinsic theories. Mauthner voices the general opinion when he states that 'the *congenital basis* of myopia is to be sought in nothing else than in a *defective resistance* of the sclerotic, especially in its posterior half.' "

"Whether in addition to a congenital weakness an *acquired factor* must also be invoked is uncertain. v. Graefe enunciated the view that the changes at the posterior pole were the outcome of a sclerochoroiditis, but he himself modified his opinion on finding no anatomical evidence of inflammation. Later observers agree that inflammatory stigmata are usually absent, Heine's careful researches being especially noteworthy; he found the degenerated retina sharply delimited by an intact lamina vitrea from the normal, though much stretched choroid and sclerotic. At the same time it must be remembered that there is little or no difference between the ultimate effects of inflammatory lesions and the condition found in myopia, and that a very slight chronic inflammation may present few objective microscopical features. It may be that the lower grades of myopia are entirely congenital in origin, whilst the higher grades of so-called progressive myopia have in addition etiologically a true inflammatory factor."

Malignant myopia. This type of myopia, unlike the acquired form, or "school myopia" as it is sometimes called, frequently manifests itself before the school age. According to Tscherning (*Physiologic Optics*, p. 86) it may sometimes be congenital and more or less stationary in character. As a rule it begins in early infancy and continues to progress throughout life. He considers the cause to be a malignant choroiditis. Priestley Smith also claims that acute syphilitic choroiditis may produce malignant myopia.

Whether there is a true dividing line between non-progressive and progressive myopia is a matter of opinion, some surgeons claiming that a case of myopia may pass through all gradations from the mildest to the most malignant forms without a dividing line, while other observers make a sharp line of distinction between the benign forms of myopia and the malignant or progressive type. But whatever the cause, malignant myopia is characterized by rapid lengthening of the eye-ball, accompanied by changes at the macula and near the disc, resulting in posterior staphyloma, and at times with detachment of the retina. Vitreous opacities are not uncommon and even partial atrophy of the optic nerve may take place. As a result, there may be an increase in the size of the blind spot, scotoma may be present from patches of choroidal and retinal atrophy, and subjective symptoms of floating specks, black spots and phosphenes are often present. The vision is always greatly impaired, and the sight may be totally lost, as hemorrhages at the macula or detachment of the retina may take place.

At times, in cases of high myopia, the tension of the eye is considerably elevated, though apparently this is the only sign of glaucoma or tendency in that direction. The writer has had such a case of high myopia (16 D., with large posterior staphyloma in each eye and marked choroidal and retinal atrophy near the margin in one) under observation for more than a year.

Not infrequently the cornea is flatter in these cases of high myopia than in emmetropia; consequently the myopia is a true *axial* one.

Curvature myopia may be due to an excessive curvature of the cornea or of either surface of the crystalline lens; or to partial displacement or luxation of the lens. In a normal eye, curvature myopia rarely exceeds in amount one or two diopters, in fact, seldom reaches that amount; and when of considerable or large amount is always associated with pathologic conditions, as conical cornea, or conical lens. In such conditions there is also an irregular astigmatism to deal with. Curvature myopia may result from operations on the eye.

The author has used the Javal ophthalmometer constantly in hospital and private practice since 1890, and after an experience covering several thousand refractive cases has been unable to find any constant relation between the radius of curvature of the cornea (in the normal eye) and the refractive condition of the eye. Donders states: "A priori, it might be supposed, and it has not only been supposed, but also asserted, that less convexity of the cornea and of the crystalline lens is peculiar to the hypermetropic eye. So far as the cornea is concerned, I am justified by the results of numerous accurate determinations in denying the assertion. Even in high degrees of hypermetropia the radius in the visual line is nearly equal to that in the emmetropic eye; in the highest degrees, when the circumference of the cornea is somewhat less than usual, I found the radius even less."

The same author draws a similar conclusion in regard to myopia, that is, that the radius of curvature of the cornea bears no definite relation to the refractive condition present. In extreme degrees of myopia, on the contrary, a somewhat flatter cornea is met with.

Donders (*Accommodation and Refraction of the Eye*, p. 246) admits such things as *curvature* myopia and curvature hypermetropia, but his ultimate conclusion is, "That *myopia usually depends upon an elongation, and hypermetropia upon a shortening, of the axis of vision.*" All subsequent observers have confirmed this view.

Schiötz (cited by A. Javal, *System of Diseases of the Eye,* Norris and Oliver, Vol. II, p. 127) has also made special investigations with the ophthalmometer as to the corneal curvature in cases of hypermetropia, myopia, and emmetropia, but found no definite relation existing between them.

Javal, in commenting on this subject, says: "It is, in fact, remarkable how greatly the radius of curvature may vary for the same refractive condition. In emmetropia the radii of curvature as measured by Schiötz varied between the limits of 8.657 mm. and 7.243 mm. or, in diopters, between 38.8 D. and 45.3 D.,—a difference of not less than 6.5 D. From these figures it would appear that variations in the radius of corneal curvature do not play any great rôle in determining the refraction. A still more conclusive proof is afforded by observations made on antimetropes. As a rule, in such persons we find the same radius of corneal curvature in both eyes, even when one of these eyes is highly myopic."

The writer's own experience has been that of the great majority of observers in not finding any definite relation between the radii of corneal curvature and the other refractive factors in the eye. Furthermore, according to the calculations of Mauthner, the radius of curvature of the emmetropic eye may vary in length between 7 and 8.50 millimeters, under which conditions the length of the emmetropic eye must vary between 22.25 and 26.24 millimeters. And since a difference in length of the eye of one millimeter corresponds to an ametropia of 2.50 D. (Tscherning) it is easily seen by this calculation that an emmetropic eye may vary 10 whole diopters in refractive power!

The radial curvatures of the cornea are, therefore, manifestly misleading as indicators of the probable dioptric condition of the eye.

Since Souter's ophthalmophakometer has been in practical use the writer has examined the posterior surface of the crystalline lens to ascertain if there is any definite relation between the curvature of that surface and the ocular refractive but found none.

Curvature myopia of any considerable amount may, therefore, be looked for only in diseased conditions of the eye—conical cornea, lenticonus, etc.

Displacement of the crystalline lens may also produce a form of curvature myopia. If the lens is luxated so that it occupies but part of the pupillary space (especially if it assumes an oblique position) the refractive power is increased and a myopic state is the result. This obtains especially in young subjects, because in rupture of the zonule of Zinn the lens assumes a more spherical shape than when held in compression by the intact zonule acting on the capsule. If the lens is displaced forward a myopic refraction is produced; but such a luxation is manifestly due to a diseased condition and should not be classed as a refractive error.

Lenticonus posterior is an unusual condition, while *lenticonus anterior* is exceedingly rare, having been reported only about five or six times in literature; one of them by the writer (*Refraction of the Eye*, p. 372). See, also, p. 7417, Vol. X of this *Encyclopedia*.

In iridocyclitis myopia has been observed, and Parsons cites a case reported by Hess where it amounted to 5 D. The writer has had under observation a case in which myopia amounted to 3 D. though the patient was placed under the full effects of atropine for about eight weeks. When the patient first came under observation, vision equalled—20/20 (with—1 D. cyl-ax. 180°), now it requires—3 D. in addition, which brings the vision from 20/200 (to which it was reduced) up to 20/20—. This large amount of myopia cannot be accounted for by an increase in the refractive index of the aqueous or lens, but must be due to an increased curvature of the lens, especially as no changes in curvature of the cornea have taken place.

Index myopia. This may be caused by an increase of the refractive index of the cornea, aqueous or lens, or to a decrease in the refractive index of the vitreous. The most common form of index myopia is that occurring in the crystalline lens of old people. It is responsible, in fact, for most cases of "second sight," which is due to hardening, and to an increase in the refractive index of the crystalline lens, especially of the nucleus of the lens in the aged. This index myopia of the lens in the aged, however, is usually followed in a short time by the formation of a cataract, so that "second sight," as a rule, ends with no sight at all. There are a few exceptions to this rule, however, where this so-called second sight is retained for years. See p. 6186, Vol. VIII of this *Encyclopedia*. The amount or degree of index myopia may even reach as high as 10 D. (Landsberg, cited by Weeks), and Weeks himself (*Diseases of the Eye,* p. 657) reports one case of 6 D.

Diabetes may be a cause of lenticular index myopia. Many such cases have been reported. The writer has had one such case (woman, aged 42) under observation for the last seven years. When first seen (1907) the patient had hypermetropic astigmatism .25 D. in right eye and .50 D. in left. In 1908, she developed a myopia of 1.50 D. and this myopia has been as great as 2.50 D. in the greatest refracting meridian (a small amount of astigmatism remaining). This myopia has varied in amount from .75 D. to 2.50 D., according to the amount of sugar present. With correction, vision remains 20/20 plus. See, also, p. 3924, Vol. V of this *Encyclopedia.*

Myopia of any considerable degree as a result of the increased refractive index of the aqueous, has not been well established, and Parsons remarks that the aqueous humor would require a refractive index equal to that of the cornea to produce a myopia of 1.50 to 2 D. Certainly, such a case would be considered as of a pathologic nature rather than one of a refractive error!

See, also, **Myopia**, p. 8265, Vol. XI of this *Encyclopedia.*

Astigmatism.

The term *astigmatism* was introduced into scientific phraseology by Whewell (q. v.) and is better understood when we note its derivation (from the Greek *a, without,* and *stigma,* a point), meaning literally "without a point," i. e., rays, derived from one point, do not again unite in one point. The condition is due to an inequality of the refracting surfaces of the eye or of their combined action.

There are two general types of astigmatism, *regular* and *irregular.*

Regular astigmatism is observed in eyes with smooth or *regular* refracting surfaces of the cornea and lens, but whose chief or principal meridians have a different refracting power, hence bring rays of light from an object to a focus at different distances back of these surfaces, or *not at a point* (astigmia). These principal meridians in regular astigmatism are usually at right angles to each other, but not always nor necessarily so. It is interesting to cite Donders on this point:

"The cause of regular astigmatism is to be sought partly in the cornea. Numerous measurements have shown that the cornea in its several meridians has a different radius of curvature; and what holds good for the dioptric system of the whole eye, namely, that the maximum of curvature usually lies closer to the vertical meridian than to the horizontal, is equally applicable to the cornea, taken by itself. It is thus established, in the first place, that the cornea on account of its form produces astigmatism; in the second place, that even if the crystalline lens has an influence, the direction given to it by the cornea in general preponderates" (*Accommodation and Refraction of the Eye,* p. 455).

Irregular astigmatism is due to a rough or irregular surface of the cornea in the vast majority of cases, and the refraction varies in different parts of one and the same meridian, as well as in various other meridians. This type of astigmatism is usually situated in the cornea and is the result of inflammatory conditions which have left its front surface rough and irregular. Donders, on the other hand, states in so many words that, "on the lens depends irregular astigmatism"; but this subject will be discussed later.

In most cases of astigmatism, both of the regular and the irregular type, it is the cornea which is at fault. And because of the fact that it separates a medium of low index of refraction (the air) from a medium of greater index of refraction (the aqueous humor) slight inequalities in the curvature of its different meridians give wider differences in the refraction than if the cornea separated media of the same density.

The *regular* form of astigmatism is congenital in most instances, though outside influences may have a bearing on its causation and increase in amount. The shape of the head itself has been given as a cause of astigmatism. Landolt (*Refraction and Accommodation of the Eye,* p. 299) is strongly of this opinion and states that even the lower degrees of astigmatism are often accompanied by asymmetry of the cranium, which is probably its primary cause. He cites Snellen and Wecker in support of his opinion.

Pressure of the eye-lids when thickened by chalazia, or when swollen from other causes, may produce astigmatism of considerable degree,

.50 to 1 D. High degrees of corneal astigmatism following operations on the eyeball are of common occurrence; as after cataract extraction, iridectomy, and, at times, after tenotomy or advancement of the recti muscles. Where the section is made above, as in cataract extraction or iridectomy, the vertical meridian of the cornea is rendered flatter or of less refractive power than the horizontal meridian. The astigmatism "against the rule" produced in this way may amount to as much as 20 D. or more (Pfingst), and the writer has observed a case where the patient accepted for permanent wear a + 11.50 D. cyl. + 4 D. sph.

Landolt has reported one case where he performed an iridectomy above and subsequently one below on the same eye, which produced a corneal astigmatism against the rule of 10 D., and two years following the operation the astigmatism still remained at 4 D.

Although astigmatism may be of high degree shortly after operations on the cornea, it usually diminishes rapidly in amount and may disappear entirely. Contraction of the straight muscles (recti) may produce corneal astigmatism from 1 to 2 D. The writer has reported one such case in the *Manhattan Eye and Ear Hospital Reports,* January, 1895, where the patient had a corneal astigmatism with the rule, .50 D., which he could, by voluntary action of the recti muscles, increase to 2 D. in the right eye, and to 1.50 D. in the left eye. When under a cycloplegic he could still increase the astigmatism in the right eye to 1.50 D., and in the left to 1 D. The lids were held from the eyes during the corneal test so they could have no influence. This might be called a dynamic corneal astigmatism, just as we may have a dynamic lenticular astigmatism, caused by an unequal contraction of the ciliary muscle.

Tenotomy of the straight muscles of the eye has resulted in so altering the shape of the cornea as to relieve an astigmatism (Geo. F. Bull); and Bull suggested operative procedure for relieving astigmatism.

Ulcers or swellings near the sclero-corneal margin may cause astigmatism, and so may a thick pterygium by traction on the cornea. We have observed such cases, and have seen the corneal astigmatism so produced almost entirely relieved by removal of the pterygium.

Irregular astigmatism. Although Donders claims that "on the lens depends irregular astigmatism," it is the irregular astigmatism of the cornea that most concerns us in every day practice. Inasmuch as the irregular form is acquired in the vast majority of cases from inflammatory processes or injury the relief afforded by glasses in both the corneal and lenticular variety is not so marked as in the regular, congenital varieties, though in some cases the visual improvement is considerable.

Lenticular astigmatism may be regular or irregular, and the regular type may be either *static* or *dynamic.* The static form is due to inequality of the refraction of the posterior surface of the lens, is of small amount (usually about .50 D., but may reach 1.50 D.), and is *against the rule* in almost every case, if not every case. Since the introduction of Souter's ophthalmophakometer (a modification of the Javal-Schiötz ophthalmometer) as a practical office instrument, the measurement of lenticular astigmatism objectively has been made practical and feasible. Furthermore, the method is fairly accurate in its measurements, especially as regards the posterior surface of the lens. The writer has used the instrument in several hundred cases and can attest its value.

The *Souter ophthalmophakometer* is a modification of the Javal-Schiötz ophthalmometer; or as Souter states, "the basis of his apparatus is the Javal-Schiötz ophthalmometer. See **Ophthalmometer,** p. 8926, Vol. XII of this *Encyclopedia.* Two radical changes in the construction of the Javal instrument were necessary to adapt it for measuring the two surfaces of the lens.

Perhaps it is best to quote Souter (*Refraction and Motor Mechanism of the Eye*, 1910) as to the nature of these two changes: "The first of these innovations is in the mires, in order that sufficient illumination may be secured for the lens measurements. The opalescent glass is made readily removable by means of a rotating disc, so that in measuring the lens the unshaded filaments of two small electric lamps are used as mires. The second innovation is required in order to adapt the instrument to the great variation in the size of the images as formed at the posterior surface of the lens and at the anterior surface with magnification by the cornea. We must provide for a variation in radius of curvature from 5 mm. for the posterior surface of the lens, to 20 mm. which represents the apparent radius when the actual radius of the anterior surface is 12 mm. The adaptation of the instrument to this great variation of curvature is accomplished by making the objective and the prism movable in the tube of the telescope. By varying in this way the relative size of the image at the eye-piece as compared with the actual image under measurement the images formed at all three surfaces can be measured. The required movement of the objective is not so great as to mar the sharpness of the images because of divergence or of convergence of the rays as they traverse the prism."

The instrument of Souter can, therefore, be used as an ordinary ophthalmometer; or, by shifting the position of the objective and the prism in the telescope (which are fixed in a collar within the tube and can be easily and instantly moved) and by exposing the circular electric filaments in the mires by removing the opalescent glass from the front surface, the curvature of the posterior surface of the lens can readily and accurately be measured. It is only with difficulty, however, that the front surface of the lens can be measured and then only with the pupil widely dilated and with patients that are coöperative. However, as Souter has pointed out, after having made measurements of the anterior lens surface in numerous patients, it will be found that observation of this surface does not contribute but in a slight measure to measurement of the total astigmia of the eye, and may in the majority of cases be neglected.

Properly to use the ophthalmophakometer, some personal instruction should be had. After using the instrument for a number of years, the writer can testify to the practical value of it, as it adds one more objective test for measuring astigmia, and brings into nearer agreement the total astigmia as measured by other objective tests (keratometry, phakometry and retinoscopy). The writer fully indorses Souter's statement, "Assuming that the cornea has been properly measured in the axis of vision, and that undue pressure by the lids has not been made on the eye under observation, I estimate that the subjective astigmia, within .25 D., can be obtained from the two usual measurements, that is, from the measurement of the cornea and the posterior surface of the lens, in at least 90 per cent. of the cases examined."

Souter (*Pray Prize Essay*) had used the instrument on more than 3,000 cases when he reported his results.

Regarding the frequency of lenticular astigmatism, he states: "In frequency of occurrence astigmia of the posterior lenticular surface equals corneal astigmia. The asymmetry of the former surface is no less than that of the cornea, but, owing to the comparatively small refractive action of the lenticular surface the resulting astigmia does not reach the high degree that occurs at the cornea." The highest degree of astigmia he observed at the posterior surface of the lens was 1.50 D. and rarely did he find as much as 1 D. The astigmatism at the posterior surface of the lens he found to be always against the rule. Such has also been the writer's experience. For the measurement of the static refraction of the anterior surface of the lens the eye must be thoroughly under the influence of a cycloplegic. Souter found that it never exceeded .75 D. and rarely amounted to as much as .25 D., and says that "We may neglect the measurement of this surface as an ordinary procedure, and yet have in ophthalmometry a method of examination sufficiently accurate to fill the requirements of an objective test.''

Souter also found that the meridian of shortest (strongest refraction) curvature of the anterior surface of the lens, like that of the cornea, is usually the vertical. Furthermore, when he did find astigmia in this situation it always offset an opposite astigmia at the posterior surface, ''so that in these cases the subjective error more nearly agreed with the record obtained from keratometry alone than with keratometry combined with phakometry of the posterior surface.'' On the other hand, if the posterior surface is symmetrical he regards it as positive evidence that the anterior surface is symmetrical. We see, therefore, that Souter practically eliminates the anterior surface of the lens as a factor in the causation of static astigmatism.

Commenting on the fact that in the astigmatism of the posterior surface of the lens the horizontal meridian is always more curved than the vertical, he accounts for it by the pressure of the external recti muscles on the globe of the eye during convergence. ''It does not seem unreasonable,'' he remarks, ''to suppose that the prolonged pressure by these muscles upon the eyeball may have some effect upon moulding the shape of the lens.''

This author also conjectures, as will later be shown, that this astigmatism of the posterior surface of lens generally neutralizes some or all of a corneal astigmatism in the opposite direction, and this accounts for the discrepancy in subjective tests and for observed differences between objective measurements and the results of subjective tests. Now that we have instruments that accurately measure objectively the curvature of the posterior surface of the lens and the anterior surface of the cornea, we are able, by adding or subtracting the results of these measurements, to calculate with precision the total corneo-lenticular astigmia.

It must be admitted, of course, that the posterior surface of the cornea may modify the result to some extent, also that a possible tilting of the lens itself may play a part in producing astigmatism; yet it is with the anterior surface of the cornea and the posterior surface of the lens that we are most concerned when estimating the total astigmatism. In this connection Souter claims that it requires a lens tilting of ten degrees to produce .50 D. of astigmatism, and that, as a rule, only about two to five degrees of tilting is found, producing not more than .12 D. of astigmatism, an amount so small as not to be taken into consideration.

Dynamic lenticular astigmatism. Dobrowolsky (*Arch. für Ophth.*

XIX, 111, p. 51, 1868) first called attention to the possibility of a *dynamic* lenticular astigmatism. He claimed that by an irregular contraction of the ciliary muscle the lens expands in an uneven way to produce an astigmatic surface; and that the astigmatism so produced neutralizes to that extent the corneal astigmatism. This theory also assumes that the corneal and lenticular astigmatism is approximately in the same meridian.

The presence of such an astigmatism in the lens was asserted largely because in some instances after an eye had been placed under a cycloplegic, the patient would accept a cylindrical glass which he did not accept previously, or that a stronger cylindrical lens would be accepted than had been accepted before. In other words, a *latent* lenticular astigmatism was assumed, which was made manifest by the instillation of a cycloplegic.

Weeks (*Diseases of the Eye,* p. 649) says on this subject: "In some cases the dynamic (lenticular) astigmia is so persistent that but part of it is manifest at first, the latent portion becoming manifest only after the patient has worn the correction for some time."

Dobrowolsky was supported in his contention by such men as Mauthner, Javal, Schiötz, Vacher, Martin, Landolt and others. Landolt thinks that: "This astigmatism of the crystalline, the inverse of that of the cornea, is oftenest what might be termed active or *dynamic* astigmatism. It is due to an unequal contraction of the ciliary muscle, which causes the lens to become more convex in one direction than in another, and for the very purpose of correcting a corneal astigmatism." Opposed to this view of dynamic lenticular astigmatism are Sulzer, George Bull, Tscherning, and others.

Although at one time the writer was of the opinion that dynamic lenticular astigmatism plays an important part in the neutralization of corneal astigmatism he no longer holds that view. This change of an opinion has been brought about by the use of the Souter ophthalmophakometer.

Souter *(loco cit.)* believes that "The reason why noteworthy astigmia is so much more frequently found in the posterior lenticular surface than in the anterior surface doubtless lies in the greater curvature of the former surface, though it is not improbable that there may be other factors."

Tscherning does not accept the theory that a congenital corneal astigmatism is often neutralized by a similar lenticular anomaly and bases his objections to it on two grounds: first, that the discrepancy between the corneal and the total astigmatism may be accounted for by the difference in the extent of the corneal surface that is brought under measurement. With a small pupil only a small area on the cornea, 3 to 4 millimeters in diameter is measured, while with a large pupil an area of 7 or 8 millimeters comes under measurement. This point will be further discussed under a later sub-section.

A. Javal thinks that "The posterior surface of the cornea is found to diminish in curvature from the center towards the periphery, as in the case of the anterior surface, and in cases of corneal asymmetry it appears also, as might be expected, to follow the asymmetry of the anterior surface. As a concave lens of asymmetrical curvature, the effect of the cornea is, therefore, to compensate in some degree the astigmatism of the anterior corneal surface as measured by the ophthalmometer.

"The maximum compensation due to this cause, so far as has been observed, is about 1 D. (as estimated for an eye in which the total astigmatism measured about 6 D.)."

From the foregoing, we see, in considering the total astigmatism of the eye, that a *regular* lenticular astigmatism must be taken into account in most cases; and further, that it is the static astigmatism of the posterior surface of the lens and not the *dynamic* astigmatism of the anterior surface (except in rare cases) that must be reckoned with. It must be noted also that the posterior surface of the cornea may be a factor in the sum of the total astigmatism, as pointed out by both Javal and Tscherning.

Irregular lenticular astigmatism. Donders finds that: "On the lens depends irregular astigmatism; to it polyopia uniocularis, to it the rays of the diffusion images of a point of light owe their origin. The direct proof of this is furnished by the fact that in aphakia, when the lens is wholly absent from the eye, all these phenomena are removed."

Lenticular opacities, as in beginning cataract, may cause irregular astigmatism. This is due to the different sections of the lens becoming unequally swollen or distorted, so that diplopia or even polyopia for one eye is often brought about. *Lenticonus,* posterior and anterior, produces irregular lenticular astigmatism, though such cases, especially of lenticonus anterior, are extremely rare.

CHAPTER II.

ACCOMMODATION OF THE EYE.

Again it may be stated that the eye has often been likened to a camera, and in many respects this comparison holds true, as having in common a darkened chamber, an aperture at the front variable in size for the admission of light, refracting surfaces, for focussing the light, and a sensitive layer or plate for the reception of the images of objects. The one marked difference between the eye and a camera lies in the different method or mechanism of bringing rays of light from objects situated at varying distances in front of it to an exact focus on its sensitive plate, the retina, which is in direct contrast with the method pursued in adjusting the plate of a camera for objects situated at different distances from it. In the camera the plate itself (the posterior part of the instrument) is moved forward or backward, according to the distance or nearness of the object, in order to obtain a clear image of the object on the plate. In the eye it is obvious that the plate or retina cannot be moved backward or forward, and consequently another mechanism is brought into use to secure clear-cut images on its surface; and it is this power possessed by the eye, which enables it to focus images of objects (situated at varying distances in front of it), correctly on its layer of rods and cones, that is known as the *accommodation* of the eye. This adjustment is brought about by an increase in the convexity of the anterior surface of the crystalline lens with slight advancement of its surface, and a very slight increase in the convexity of the posterior surface of the lens. That such changes do take place in the lens has been conclusively proven. The means or mechanism by which these changes in the lens, and the other accompanying phenomena of accommodation, are brought about, has been the subject of many theories and endless discussions. It was not until 1867, when Helmholtz propounded his theory of the mechanism of the accommodation of the eye, that a satisfactory explanation was forthcoming. Even this explanation has been questioned by some investigators, so great an authority as Tscherning (of whose theory we shall speak later) taking issue with it.

Historical. Space does not permit a review of the many theories of the mechanism of accommodation, but it may be said that the first to give a somewhat feasible explanation of the mechanism of accommodation was Kepler, who advanced the theory that the crystalline lens was projected forward during the act of accommodation. To Descartes (Landolt, *Refraction and Accommodation of the Eye*, p. 149) belongs the credit of suggesting an increased curvature or convexity of the lens during accommodation. Landolt says that "The first to ascribe this variation in the refraction of the eye to a change in the form of the crystalline lens seems to have been the Jesuit, Scheiner (1619)." Following Scheiner in chronological order Landolt places Descartes (1637), Pemberton (1719), Camper (1746) and Hunter (1794).

Increase in convexity of the cornea and increase in the length of the eyeball itself have each been claimed to explain the mechanism of accommodation. Arlt was of the opinion that the eye was lengthened by the action of the extrinsic muscles. Numerons other hypotheses were advanced to account for this phenomenon, but it was not until 1801, when Thomas Young (*Philosophical Transactions,* Vol. XCII, p. 23, 1801) made actual demonstrations of changes in the curvature of the surfaces of the crystalline lens, during the act of accommodation, that any real proof as to the nature of the mechanism of the accommodation was brought to light. Tscherning says that Young first *demonstrated* that accommodation was effected by an increase of the lens surfaces and had more exact ideas on what happened during accommodation than observers of our own time.

At this date the ciliary muscle had not been discovered, and Young attributed the change of form in the lens to the contractility of the lens fibres themselves. Although Young brought positive demonstration to the support of his theory of accommodation it attracted at the time little notice. The reason for this, according to Donders, is that "Physiologists, not being acquainted with any muscular elements in the eye, could scarcely imagine by what mechanism the crystalline lens could change its form, and they were little inclined to believe with Young in the contractibility of the fibres of the lens."

Purkinje advanced a step when he discovered his *catoptric images* (see p. 1784, Vol. III of this *Encyclopedia*) in 1823. However, it remained for Maximilian Langenbeck (*Klin. Beiträge aus d. Gebiet d. Chir. u. Ophthal.*, Gottingen, 1849) and Donders to make use of these images in further solution of this question. Finally, Cramer studied the Purkinje images under magnification, with an instrument which he at first called an "ophthalmoscope," but which Donders later modified and called a phacoidoscope. Cramer's instrument magnified the images so that they could be seen clearly and could be accurately measured; and demonstrated in a definite manner that the image from the anterior surface of the lens changes in size (becoming smaller) and in position (drawing nearer to the image from the cornea) when in accommodation for the near point. Helmholtz, subsequently, made the same observations, and in addition he observed that the images from the posterior surface of the lens become slightly smaller in accommodation, and that its surface becomes slightly more convex, though it does not move forward as does the anterior surface of the lens, since the image does not change *position.*

That one may see the Purkinje catoptric images to best advantage, the observer should hold a light at an angle of about 30 degrees with the optic axis on one side while he takes his position of observation at an angle of the same number of degrees on the other side. If the images are magnified, as in the phacoidoscope, their relative size and position can be studied to the best advantage.

In Fig. 4 are shown the size and position of the images when the eye is in a state of rest and again when in the act of accommodation B. In each half of the figure, *a* is the image from the cornea, *b* from the anterior surface, and *c* from the posterior surface of the lens. It is seen that *a* is the brightest, because the cornea separates a medium of rare index of refraction (the air) from a denser medium, the aqueous. The images from the lens surfaces are dimmer because the lens separates media of the same density (the aqueous and vitreous) that have an index of refraction not greatly differing from the lens itself.

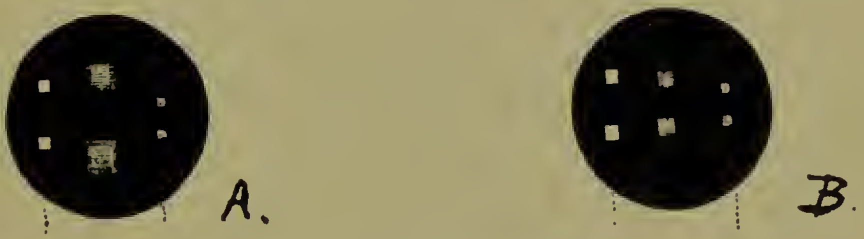


Fig. 4. Catoptric Images.

A, position of the images when the eye is accommodated for distant objects; B, position of the images when accommodated for near objects; *a*, corneal image; *b*, image from the anterior surface of the lens; *c*, image from the posterior surface of the lens. (After Helmholtz.)

The image from the cornea is smaller than the image *b* from the anterior surface of the lens because the cornea has a shorter radius of curvature (and consequently a more convex curvature) than has the anterior surface of the lens; while it is larger than the image from the posterior surface of the lens, because it has a longer radius of curvature (consequently a less convexity) than has the posterior surface of the lens. In the act of accommodation the image from the cornea remains stationary, while the image from the anterior surface of the lens becomes smaller and approaches that of the cornea. Helmholtz independently made the further observation that the small image *c* from the posterior surface of the lens became slightly smaller in accommodation, though it did not change position. The schematic Fig. 5 demonstrates how this change in the size and position of the image from the anterior surface of the lens takes place.

A A′ is the axis of the cornea, with which we here assume that the axis of the lens L coincides. The lens is drawn in a double form, namely, with continuous lines in the form of accommodation for distant, and with dotted lines in the form of accommodation for near objects. At *f* is a flame; at *o* the eye of the observer. These two are so placed that lines proceeding from them cut each point of the axis at similar angles. Therefore, the rays thrown back by the reflecting surfaces of the observed eye, where these changes are cut by the axis, reach the eye of the observer.

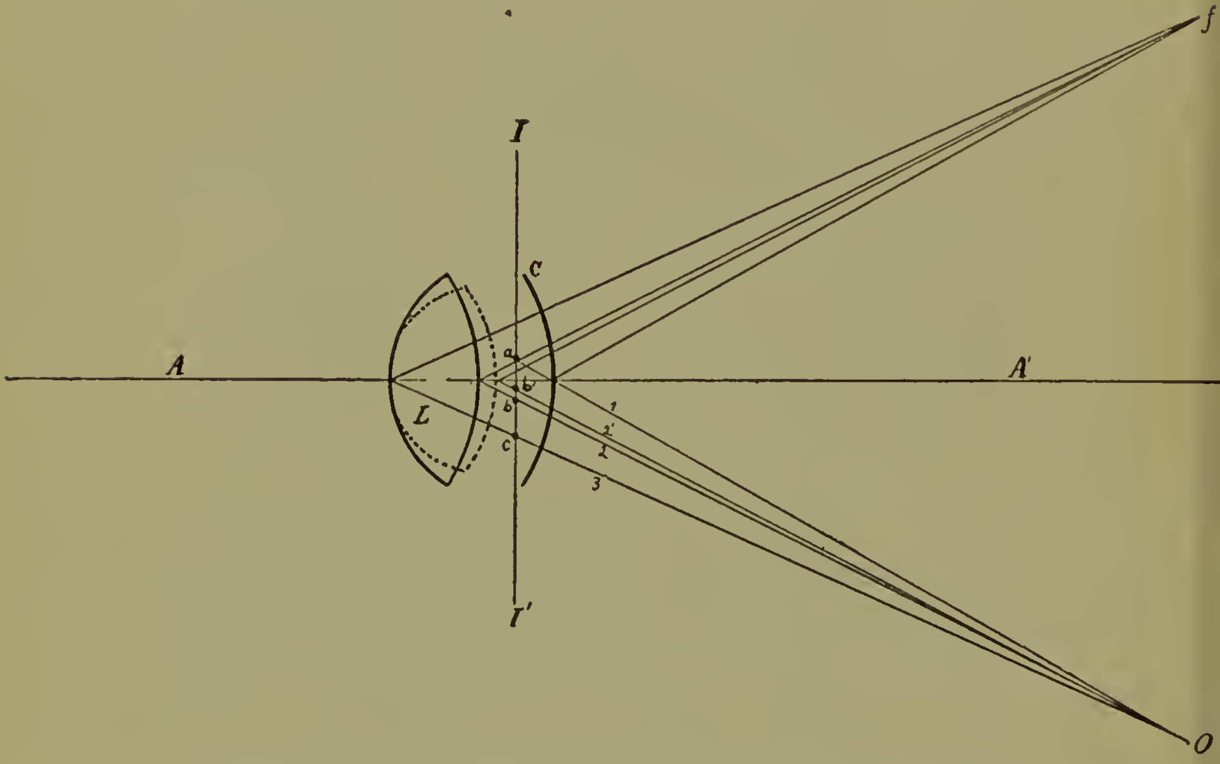


Fig. 5. Schematic Figure Showing Change in Size and Position of Catoptric Images. (After Donders.)

The reflecting image of the cornea is consequently seen in the direction *O* 1, and (disregarding refraction on surfaces situated in front) that of the anterior surface of the lens in the direction *O* 2, that of the posterior surface in the direction of *O* 3. Projected on the surface 1 1′, they appear close to one another as *a*, *b*, and *c* (compare also Fig. 4, A). If now the anterior surface of the lens advances to the dotted line, the second image is seen in the direction *O* 2′, and is therefore projected on the surface 1 1′, and *b*′; it has consequently approached the reflex image *a* of the cornea (compare the preceding figure 4 B). From this change of place, which is easily observed, we therefore infer that, in accommodation for near objects the anterior surface of the lens approaches the cornea. It is, indeed, true that we do not see the images *b* and *b′* exactly in the direction of the point where the axis cuts the surface of the lens, because both the incident and the reflected ray is refracted by the cornea in front. But in consequence of the symmetrical position of the eye *O*, and the flame *f*, with respect to the axis, the deviations so produced are equally great on both sides, and the above inference, therefore, remains quite correct. If we determine the direction of the radius of the cornea in this place, where the ray reflected on the anterior surface of the lens enters and leaves the latter, we can, from the distance between the images *a* and *b* and *a* and *b′*, calculate the distance from the anterior surface of the lens to the cornea.

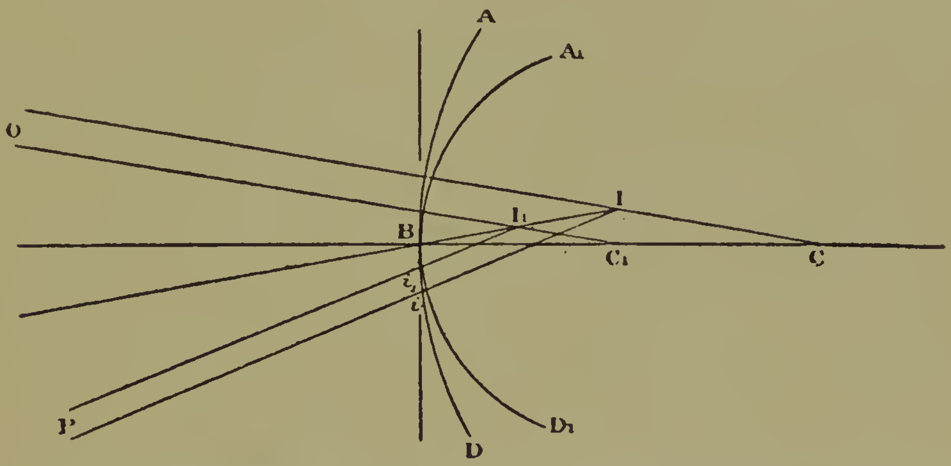


Fig. 6. Centripetal Movement of the Catoptric Image of the Anterior Surface of the Crystalline Lens During Accommodation. (After Tscherning.)

Tscherning (*Physiologic Optics,* 1900) gives a somewhat different schematic figure (Fig. 6) to show the change in position of the image from the anterior surface of the lens in accommodation (which he designates as a centripetal movement) in which the anterior surface of the lens is not represented as moving forward. The following is his own description of the figure: "Let ABD be the surface in a state of repose and C its center; A1BD1 the surface in a state of accommodation and C1 its center; O an object (a lamp placed at a great distance). To find the position of the image, we draw OC (OC1) (supposing that these are the apparent surfaces we need not take into account the corneal refraction). The image must be on this straight line, at an equal distance between the surface and the center, at 1 for the surface in repose, at 1′ for the surface in a state of accommodation. The observing eye sees the images projected in the pupillary plane, it sees I at i and I′ at i′; it sees the image, therefore, make a centripetal movement during accommodation. It is the same, whatever may be the position of the observing eye; there is only one point where it does not see motion, viz., when it is on the prolongation of the line II′: in this case the two images I and I′ overlap, and there is no apparent displacement. The line II′ passes through the point B, the place where the two surfaces touch. This point B, towards which the apparent movement of the image takes place, whatever may be its position in the pupil, is usually situated a little outside the center of the latter; generally it is found almost on the optic axis of the eye.''

Tscherning adds: ''But, as the thickness of the crystalline lens is only 4 mm. an error of half a millimeter presents a vast importance. The much disputed question whether the crystalline lens changes its thickness during accommodation can with difficulty be decided by the observation of the crystalline images, for the alleged change (an increase of 0.4 mm.) does not exceed the limit of error.''

However, Helmholtz's theory of accommodation has been generally accepted, and it is all but universally agreed that the changes which take place in the eye during accommodation for near objects are: (1) The anterior surface of the lens becomes more convex and advances slightly towards the cornea; (2) the posterior surface of the lens becomes slightly more convex, but does not change position. These changes in the crystalline lens are commonly believed sufficient to account for all the accommodation of which the eye is capable, as H. Knapp (*Arch. f. Ophthalm.,* VI, 2, p. 1, 1860) by the measurements he made in four eyes and the calculation therefrom has fully demonstrated.

Helmholtz made similar observations later and also measured the dead crystalline lens in support of his theory of accommodation. Donders, entirely convinced by the accuracy of Knapp's measurements and conclusions, also held that besides the changes which take place in the lens no others occur in the dioptric system in accommodation. He states further, ''I have satified myself that where the crystalline lens is absent, even in young people, not the slightest trace of accommodative power remains.'' [With this latter statement of Donders, we must take issue. In common with others the writer (*Manhattan Eye and Ear Hospital Reports,* Jan., 1895) has observed accommodation in the lenseless eye. One such case, in an aged man, was reported at length and demonstrated to others. Briefly the case is as follows: An eye had a small oblong pupil, about 2 mm. in its narrower diameter, while the remainder of the pupil, after the extraction of cataract, was blocked by a membrane. All the diffraction rays were cut off in this way and allowed the light that entered the eye to come to a fairly well defined focus on the retina. When one considers that the images so formed are about 1⅓ larger than in the normal eye it will be understood how this patient was able to read fine print at eight inches with his distance glasses, and without moving the latter in any way. Since the above was written the author has encountered another case of apparent accommodation in a patient aged 73, following cataract extraction. The pupil was oval 1½ x 2½ mm., and the patient, with her distance glass without change of position, read Jaeger No. 1, at 7 inches easily.

The mechanism of accommodation.

Although the experiments of Young, Langenbeck, Donders, Knapp, Cramer, Helmholtz and others definitely settled the character of the changes which take place in the crystalline lens when the eye was accommodated for near objects, no satisfactory explanation as to *how* these changes were brought about was forthcoming until Helmholtz (*Handbuch der physiologischen Optik*, p. 110) gave to the world his celebrated theory. This theory briefly is as follows: When the eye is at rest the fibres of the zonula of Zinn (see p. 381, Vol. I of this *Encyclopedia*) are stretched, their traction on the lens capsule flattens the lens and the eye is adjusted for its distant point of vision, or *punctum remotum*. When, however, the ciliary fibres, having their origin near the sclero-corneal junction, contract, the choroid is drawn forward, the ciliary body is thickened, the zonular fibres are relaxed and the tension being removed from the lens capsule the lens expands through its own elasticity, its surfaces become more convex and it approaches a more spherical form. The anterior surface of the lens at the same time moves slightly forward (the posterior surface remaining stationary) while the pupil contracts slightly, with some recession of the iris at the iris angle. These are the changes embraced in the act of accommodation or adjustment of the eye for near objects.

The nearest point to which the eye can adjust itself is called *punctum proximum;* and the distance between the far point and the near point is called the *region* of accommodation.

The difference in the refractive power of the eye when adjusted for the near point (p.p.) and when adjusted for the remote point (p.r.) is designated the *range* or *amplitude* of accommodation.

The theory of the mechanism of accommodation advanced by Helmholtz was strengthened by the investigations of Hensen and Voelkers (*Experimentaluntersuchungen über den Mechanismus der Accommodation*, Kiel, 1868; also *Arch. für Ophthal*, XIX, 1, 1873). These investigators experimented on dogs, cats, and on the human eye just after its removal. They exposed the ciliary ganglion in the eyes of animals, then stuck fine needles through the sclera into the choroid near the region of the ora serrata. On stimulating the exposed ciliary nerves by electricity the free ends of the needles were seen to move backward, showing that the choroid was drawn forward. Further, they introduced two needles into one eye, the point of one touching the anterior surface, the point of the other needle touching the posterior surface of the lens; on applying the electric current to the ciliary ganglion the free extremities of the needles approached each other, the anterior needle moving much more decidedly than the posterior, thus proving that the lens becomes thicker during the act of accommodation. These investigators also observed directly the action of the ciliary muscle by removing a small section of the sclera near the sclero-corneal margin. Other phenomena observed during the electric stimulation of the ciliary ganglion were a marked contraction of the pupil, that the pupillary margin of the iris was advanced, and that the peripheral border of the iris was retracted. The observations of Coccius and Hjort also tended to strengthen Helmholtz's theory. Coccius made his observations in eyes upon which large iridectomies had been performed, while Hjort made his in a case of traumatic aniridia. Both these investigators found during accommodation that the ciliary processes advance and increase somewhat in bulk, and that the equatorial rim of the lens becomes a little broader.

Coccius was also of the opinion that the space between the ciliary processes and the edge of the lens becomes a little wider. Another phenomenon, which accords with Helmholtz's theory, is the so-called accommodation-phosphene of Czermak and Purkinje. During the act of accommodation and at its termination, when the ciliary muscle relaxes, there may be observed in a darkened room a kind of halo at the periphery of the field of vision, which shows that the retina corresponding to that part of the field has been irritated or had traction placed on it.

Tscherning (*Physiologic Optics*) has advanced a theory of his own. In the author's own words, "*accommodation is affected by the temporary formation of an anterior lenticonus.*" He claims that this condition of the anterior surface of the lens is brought about by a tension or traction on the zone of Zinn, which in turn puts a tension on the capsule of the lens and this traction on the capsule increases the convexity of the surfaces of the lens at the middle while flattening them towards the periphery, the anterior surface assuming the shape of a flattened *hyperboloid.* This condition is supposed to be brought about by actual *compression.* It will be seen that this theory is in direct opposition to that of Helmholtz, which latter assumes that in accommodation the zonule of Zinn is relaxed, and that the pressure being taken off the capsule, the lens expands of its own elasticity and its surfaces become more curved, especially the anterior surface. That is, Tscherning's theory assumes compression, while Helmholtz's rests on the *elasticity* of the lens. See, also, the corresponding sub-head under **Physiological optics**, in this *Encyclopedia.*

CHAPTER III.

CONVERGENCE.

When looking at an object in the distance (infinity) with the visual lines of the eyes parallel the image of the object falls on corresponding points in the two eyes, and are perceived at the visual center in the brain as a single image. This is termed *binocular single vision* and also *binocular fixation.* When an object is seen singly by the two eyes at any point nearer than infinity the visual lines must be turned inward or converged to an equal degree, and this function is designated *convergence.*

In looking at an object the eyes are so directed that the image of the object falls on the center of vision, the fovea centralis, in each eye, the most sensitive point in the retina. When so directed, the eyes are said to ''fix'' the object; if one eye alone is used it is termed *monocular fixation,* if both eyes, *binocular fixation.*

Investigators have shown that the fovea centralis is chiefly concerned with the function of fixation.

Images of objects falling at corresponding points on the retinæ outside the center of vision (fovea centralis) are also seen singly; for example, when at the same distance to the right of each fovea, or to the left, above, or below, the essential thing being that the images fall on corresponding points in the two eyes. See p. 3539, Vol. V of this *Encyclopedia.*

As is well known, images projected on the left side of the retina are seen in the right field of vision, and those on the right side of the retina in the left field of vision; while the images that fall on the upper half of the retina are seen in the lower field of vision, and those that fall on the lower half of the retina are projected into the upper field of the vision.

With the visual lines of the eyes parallel, as when looking at a distant object (infinity), the convergence is *nil;* when the visual lines converge, as when fixing all near objects, the convergence is *positive;* when the visual lines diverge, the convergence is *negative,* that is, divergence is present. In the last instance, if the visual lines are extended backward they meet back of the eye.

The degree or power of convergence is expressed in the term of *meter-angles,* one meter-angle being taken as the unit, just as the *diopter* is used as the unit of measure in expressing the accommodative power of the eye. A meter-angle of convergence is the angular distance the visual line of each eye traverses when these lines are brought from a parallel position to a point of intersection on the median line one meter distant in front of the eyes.

The distance between the centers of rotation of the eyes, the base line, must be taken into consideration in determining the meter-angle. The average length of the base line in children is 58 mm. and in adults 64 mm. and one-half this distance, respectively 29 mm., and 32 mm. is the sine of the meter-angle; and it is upon these base lines that the value of the meter-angle is determined for various distances in front of the eyes.

To fix an object one meter in front of the eye requires one meter-angle of convergence, a linear deviation of 29 mm. in a child and 32 mm. in an adult. To fix an object at twice this distance (2 meters) it would require only one-half the power of convergence as for a point one meter distant, or ½ meter-angle of convergence; while to fix an object at ½ meter distance would require twice the converging power as for a distance of one meter, or 2 meter-angles of convergence. For 1/5 of a meter distance 5 meter-angles of convergence would be necessary to fix an object, and so on. See, also, **Angle, Metre,** p. 473, Vol. I of this *Encyclopedia.*

It will be seen that the degree of convergence increases in an inverse ratio with the distance of the near-point of fixation, just as the power of accommodation increases inversely with the near-point of vision.

The *range* of convergence is the distance between the extreme far-point and the nearest point of convergence.

The *amplitude* of convergence is the sum of the minimum and the maximum power of convergence, that is, the force required to bring the eyes from the farthest point of convergence to the nearest point.

As stated above, for all points nearer than infinity the convergence is *positive,* at infinity (parallelism) it is *nil,* and for points beyond infinity it is *negative.*

Again, the degree or amplitude of convergence may be measured by prisms and registered in prism degrees. Landolt says on this point, "It is not difficult to show the relation existing between the strength of any prism and the number of meter-angles which expresses the deviation produced. For a base line (or distance between the centers of rotation of the two eyes) of 58 millimeters, as in children, a meter-angle corresponds to 1 degree 39′ 39″—say 100′.

"The deviation produced by a prism may be taken at half its angle of opening, which is marked on each prism in our trial cases, or on the handle of the double prism. Therefore, a prism of X degrees will produce a deviation of $\frac{X \text{ degrees}}{2}$ or of $\frac{X \times 60'}{2}$. It is only necessary to divide this value, by 100 in order to obtain the corresponding number of meter-angles: $\frac{X \times 60'}{2 \times 100}$.

"This formula reduced to its simplest expression becomes $\frac{3X}{10}$, that is to say, we have only to multiply the number of the prism by 3, and divide the prism by 10, in order to find, in meter-angles, the deviation for a base line of 58 millimeters.

"When the prism is held before one eye only, as in the determination of the minimum of convergence by the double prism, its action is divided between the two eyes. The total deviation $\frac{3X}{10}$ gives for each eye $\frac{3X}{20}$. A prism of 6 degrees produces a deviation of $\frac{18}{20} = 1.8$ meter-angles. But if both eyes concur to neutralize this effect, each eye need only change its direction $\frac{18}{20} = 0.9$ meter-angle. It is only when the prism of 6 degrees is placed before each eye that the full result of 1.8 meter-angles is obtained; always, of course, for a base line of 58 millimeters.

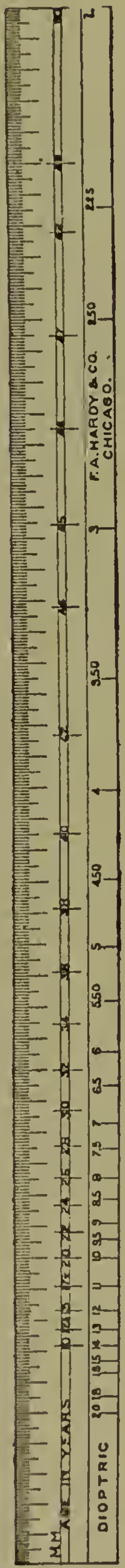
"When the base line is longer, for example, 64 mm., as in adults, the meter-angle becomes 1 degree 50′ equals 110′, and the formula becomes $\frac{3X}{11}$ for the deviation corresponding to the prism of X degree, or $\frac{3X}{22}$ for the effect produced on each eye when the prism is placed before one eye only." (Landolt, *Refraction and Accommodation of the Eye,* p. 287.)

[Prince's refraction rule is a device intended for the determination of the approximate range of the accommodation. It may be fitted with a sliding holder for holding a small card of test type. See cut.]

Clinically, to obtain quickly the amplitude of convergence, it is only necessary to take a tape, marked in centimeters, and ascertain the nearest point to which the eye can converge. Divide 100 by this number to get the *positive* part of the convergence. Say the near point of convergence is 10 cm., 100 divided by 10 equals 10 meter-angles for the positive convergence. If negative convergence is absent this represents the entire amplitude of convergence: but if by the use of prisms a negative convergence is demonstrated, as shown by the abduction point expressed in prism-degrees, reduced to meter-angles after the formula suggested by Landolt, this amount should be added to the positive part of the convergence in order to obtain the amplitude. Say the patient's abduction is 4 degrees. This reduced to meter-angles equals .6 meter-angle. The positive convergence, 10 meter-angles as measured by the tape, and the negative convergence of .6 meter-angle, as ascertained by calculation, equals 10.6 meter-angles, the amplitude of convergence in this case.

Landolt has given 10.50 meter-angles as the average amplitude of convergence, and it may be stated that this is the most satisfactory way of measuring the convergence. Even when the measurement by means of prisms (prism convergence test) indicates an insufficiency, if the amplitude of convergence comes near the normal, simply correcting the error of refraction is all that is necessary in most cases, aided in some, however, by exercise and tonics.

The relation between convergence and accommodation. There is an intimate association of the functions of accommodation and con-



Prince's Refraction Rule.

vergence, and usually when one is called into action the other participates; or when one is in repose the other is likewise.

To give examples: Take an emmetropic eye; an object at a distance of 33 centimeters (13 inches) requires 3 D. of accommodation and 3 meter-angles of convergence to be seen correctly in single binocular vision, and at 50 cm. (20 inches) 2 D. of accommodation and 2 meter-angles convergence; while for the distance or infinity no accommodation is required nor convergence. Although this association between the accommodation and convergence is very close, either can be exercised to a certain extent independently of the other. For instance, when the eyes are converged and focused for a certain point, minus glasses may be placed in front of the eyes and the object still be seen distinctly and singly; or plus glasses may be interposed with the same result. The accommodation thus brought into play is termed relative accommodation, that by the minus glasses *positive relative accommodation,* and that by the plus glasses, *negative relative accommodation.* The power of the glass that can be overcome, distinct single binocular vision being maintained, is the measure of the degree of relative accommodation.

Again, with an object fixed and focused at a certain point, the same amount of accommodation may be maintained, while the degree of the convergence is made to change by placing prisms in front of the eyes, apices either in the nasal or temporal direction. A number of prism degrees may be overcome with distinct binocular single vision maintained. Donders has shown the relation between accommodation and convergence, not only as to relative convergence, but as to their inter-relation in the production of strabismus. And Landolt has shown that about ⅓ of the amplitude of accommodation must be held in reserve for sustained, comfortable vision, while a relatively larger amount of the amplitude of convergence must be held in reservation, if sustained use of the eyes is to be maintained.

With one eye covered the other can accommodate for a point, almost, but not quite as near the eyes as when both are open, that is to say, the binocular nearpoint is a little closer to the eyes than the monocular. In other words one function stimulates the other. This is shown in cases of high degrees of hypermetropia, where a large amount of accommodative power is required, and where frequently the convergence is so stimulated that it over-acts, and we have convergent strabismus. Again, in high degrees of myopia, the accommodation is entirely relaxed, being an important factor in the production of divergent strabismus. For further explanation of the relation between convergence and accommodation in the production of strabismus, see **Muscles, Ocular.**

Angles alpha and gamma.

The *angles alpha and gamma* (see p. 470, Vol. I of this *Encyclopedia*) have a bearing on the centering of the refractive surfaces of the eye, especially as affecting their movements and parallelism.

If the center of curvature of all the refracting surfaces of the eye (the cornea, the anterior, and posterior surfaces of the crystalline lens), were in exact line, and their axes coincided with the optic axis, the angles alpha and gamma would not exist.

Tscherning (*Physiologic Optics*, p. 37) states that, "The defect which I have most frequently met consists in this, that the center of curvature of the cornea is situated as much as a quarter of a millimeter below the axis of the crystalline lens." Helmholtz and Knapp (cited by Landolt, *Accommodation and Refraction of the Eye*, p. 119) have found that the center of curvature of the anterior surface of the crystalline lens is sometimes situated as much as two degrees to the temporal side of the corneal axis.

The above variations as a rule are small in amount and for practical purposes we may consider the optic axis, and the long or major axis of the cornea as well as the antero-posterior axis of the lens, as coinciding and forming one line or axis. This line or axis which extends from the center of the cornea to the posterior pole of the eye is called the *optic axis* (xy, Fix. 7).

The posterior pole of the eye is situated between the optic nerve entrance and the fovea centralis.

The *line of vision*, FO, Fig. 7, extends from the point looked at or fixed, through the nodal point on the optic axis, to the fovea centralis. The *line of fixation*, O M, Fig. 7, extends from the point looked at or *fixed* to the center of rotation of the eye.

The figure produced to show the angles alpha and gamma is very diagrammatic. It represents the right eye as seen from above. XY, the optic axis, is in the line joining the center of the cornea and the posterior pole of the eye. CD is the longest axis of the corneal ellipsoid. In the figure, the apex (C) of the corneal ellipsoid is represented as being far to the temporal side of the center of the cornea, the spot on the cornea cut by the optic axis, XY. As a matter of fact, these points almost coincide, and are so treated in actual practice. This being so, the long axis (CD) of the corneal ellipsoid and the optic axis (XY) would coincide, and they, also, are considered as one and the same in actual practice. When they are so considered, the angle gamma, formed by the line of fixation, OM, and the optic axis, XY, varies, that is, increases and diminishes, in exact proportion with the angle alpha. Moreover, these angles become nearer equal the farther the object of fixation is removed from the eyes, and, when the object is at twenty feet or more, they become equal.

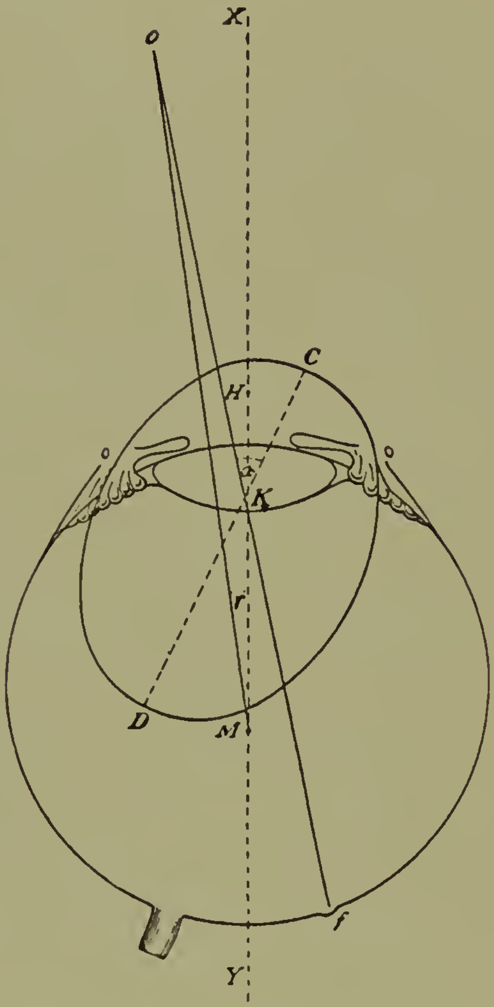


Fig. 7. Showing Different Lines and Points of the Eye.

XY, Optic axis; *H,* principal points combined; *K,* nodal points combined; *M,* centre of motion; *fO,* line of vision; *MO,* line of fixation; *CD,* greater axis of corneal ellipsoid; *OKC,* angle α; *OMX,* angle γ. This figure is very diagrammatic, in order to show the angles α and γ plainly. The long axis of corneal ellipse should, and practically does, coincide with the optic axis of the eye. (After Roosa.)

The angle alpha, OKC, is called positive, or plus, when the front portion of the long axis of the corneal ellipsoid falls to the outer or temporal side of the visual line, and this is the case in most eyes. It is said to be *negative,* or minus, when the front portion of the long axis of the corneal ellipsoid falls to the inner or nasal side of the visual line. This is comparatively rare, but sometimes occurs in myopia. When the visual line and the long axis of the corneal ellipsoid coincide, it is evident that there can be no angle at all; and then it is said to be *nil*.

It should be remembered that the optic axis and long axis of the corneal ellipsoid are regarded as one in practice, as represented in the two last figures. As long as the macula is situated to the outer or temporal side of the posterior pole of the eye, the angle alpha must be positive, as when the visual line, FO (Fig. 8), cuts the cornea to the inner or nasal side of the optic axis, XY. Furthermore, the farther the macula is situated toward the temporal side of the posterior pole of the eye, the larger will the positive angle alpha be. If the macula lutea and the posterior pole of the eye are at the same spot, then the visual line and optic axis must coincide; and there is no angle alpha. If the macula lies to the inner or nasal side of the posterior pole, the visual line, FO (Fig. 9), must cut the cornea to the outer or temporal side of the optic axis, and the angle alpha becomes negative; and the farther inward from the posterior pole of the eye the macula is situated, the larger the negative angle alpha will be.

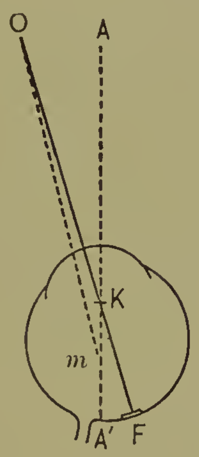


Fig. 8. Positive Angle *alpha* of Twelve Degrees, Right Eye.

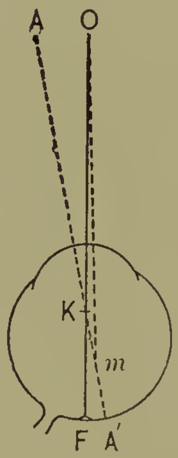


Fig. 9. Negative Angle *alpha* of Six Degrees, Right Eye.

The length of the eyeball itself influences the size of the angle alpha.

In emmetropia, the angle alpha is positive, and averages 5 degrees; in hypermetropia it is positive, and averages 7.3 degrees in non-squinting eyes; while, in myopia it is, as a rule, positive, but may be nil or negative, and averages a little less than 2 degrees.

These are the figures given by Donders: and this author explains the influence of the length of the eye-ball on the size of the angle alpha, as follows: "The distance, kg (Fig. 10), from the nodal point to the retina is to be taken in account. It is evident that, if in the hypermetropic eye, where this distance is particularly short, the yellow spot, 1, is only at the ordinary distance from g (a point of the prolonged axis of the cornea), the angle alpha, under which 1i and ga intersect one another in k, becomes greater. In this, therefore, really lies in part the cause of the greater value of the angle alpha in hypermetropic eyes; but for the most part this greater value must still be explained by the more external position of the yellow spot.

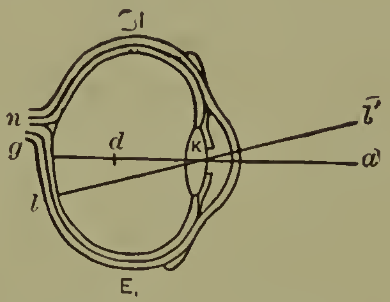


Fig. 10. (After Donders.)

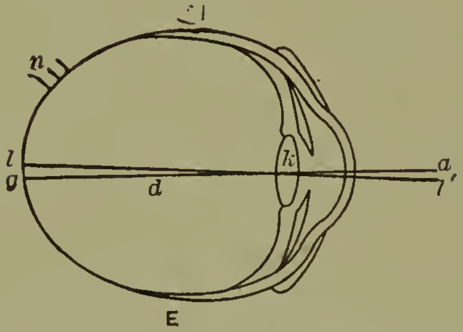


Fig. 11. (After Donders.)

"This position is connected with the arrested development, especially of the external portion of the hypermetropic eye." A glance at Fig. 11 shows the influence of myopia to diminish the size of the angle alpha, by reason of its longer optic axis.

The bearing of the angle *alpha* as a causative factor in strabismus is considered later.

CHAPTER IV.

PRESBYOPIA.

The first and chief clinical symptom of presbyopia is the recession of the near-point (p.p.) manifested by the aging patient holding printed matter, sewing, and so forth farther from the eyes than the ordinary reading distance (13 inches, or 33 centimetres). Another symptom is tiring of the eyes when close use is persisted in; especially is this the case if a small amount of astigmatism be present which has not been corrected, and even headaches may follow prolonged effort. Asthenopic symptoms in presbyopic individuals, however, are rare, the patient most frequently complaining that he cannot see print close at hand, and for this reason seeks the advice of an oculist.

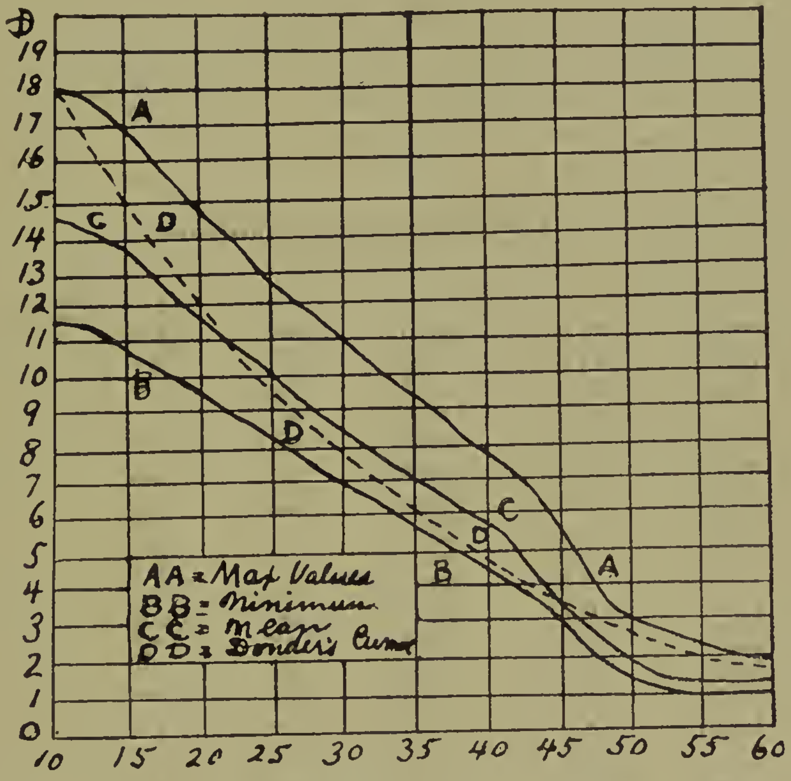


Fig. 12. Range of Accommodation in D, at Different Ages as Determined by Duane.

The near-point, from the anterior focus of the eyes, equals 13 mm. in front of the cornea. AA, maximum limit in normal cases; B B, minimum limit; C C, mean values; D D, mean as found by Donders.

The causes of presbyopia are, first and chiefly, loss of elasticity of the crystalline lens; second, in a minor degree, *perhaps* a reduction in power of the ciliary muscle itself, assuming that the strength of this muscle, as with other muscles, decreases in advanced age.

As is well known, the elasticity of the lens begins to decrease at the early age of ten years or before, and gradually decreases (the power of accommodation decreasing *pari passu*) until the age of 75 years has been reached, when the lens does not respond to the action of the ciliary muscle and there is consequently no range of accommodation. When the range of accommodation has decreased until the patient cannot see fine print closer than 22 centimetres (8 inches), presbyopia, or old sight, has set in. Eight inches, the near point, expressed in lens diopters equals 4.50 D. the amount of accommodative power necessary to see clearly at this distance, and, as a rule, obtains in emmetropic eyes when the patient has reached 43 to 45 years of age.

This is an arbitrary standard fixed by Donders, and based on the observation of the range of accommodation in emmetropic eyes. Donders' table of the range of accommodation for different eyes has been modified by Duane.

Limits of accommodation.

Age	Mean	Minimum	Maximum	Age	Mean	Minimum	Maximum
10	14.2	11.5	18.0	36	6.9	5.5	9.0
11	14.1	11.5	17.5	37	6.7	5.4	8.7
12	14.0	11.0	17.5	38	6.5	5.2	8.4
13	13.7	11.0	17.0	39	6.2	5.0	8.2
14	13.4	10.5	17.0	40	6.0	4.8	7.8
15	13.1	10.4	16.5	41	5.6	4.5	7.4
16	12.8	10.2	16.0	42	5.2	4.2	6.9
17	12.5	10.0	15.5	43	4.8	3.9	6.4
18	12.2	9.7	15.5	44	4.3	3.5	6.0
19	11.9	9.5	15.0	45	3.8	3.0	5.4
20	11.6	9.2	14.5	46	3.4	2.7	4.9
21	11.3	9.0	14.0	47	3.0	2.4	4.4
22	11.0	8.8	13.5	48	2.5	2.0	4.1
23	10.7	8.6	13.5	49	2.2	1.7	3.4
24	10.4	8.3	13.0	50	1.9	1.5	3.0
25	10.1	8.1	12.5	51	1.7	1.3	2.5
26	9.8	7.8	12.5	52	1.5	1.2	2.3
27	9.5	7.6	12.0	53	1.4	1.1	2.0
28	9.2	7.4	11.5	54 to 57	1.3	1.0	1.9
29	8.9	7.1	11.1				
30	8.6	6.9	11.0				
31	8.3	6.7	10.0	58 to 62	1.2	0.9	1.8
32	8.0	6.4	10.1				
33	7.7	6.2	9.8				
34	7.4	5.9	9.5	63 to 70	1.1	0.9	1.5
35	7.2	5.7	9.3				

In this table the maximum and minimum limits of accommodation are given for different ages up to 60 years. Beyond 60 years there still remains a small power of accommodation, gradually diminishing until 75 years is reached, when it disappears altogether.

According to the above table it will be seen that a patient at 45 years of age has an accommodative power of only 3.50 D. expressed in centimeters 29 plus (11.50 inches). His range, or amplitude of accommodation has been reduced 1 D., and his near-point has receded to 29 centimeters from the eye, compared with the normal emmetropic eye of a patient of 40 years of age.

It is evident that the patient would require a + 1 D. to read fine print at 22 cm. were he emmetropic. If hypermetropic, this amount, + 1 D., would have to be added to his distance glass, e. g., say the hypermetropia amounted to 3 D.; 1 D, added to 3 D. equals 4 D., the glasses needed for reading. If myopia is present the + 1 D. added to the negative glass which represents the myopia present is the glass to prescribe. Say there is a myopia of — 3 D., + 1 D. added to — 3 D. equals — 2 D., which is the glass to order for reading.

A presbyopic patient, up to 75 years, still has some range of accommodation, which is expressed by the focal distance of the glass necessary to bring his near-point (p.p.) up to the standard at 40 years of age, 22 cm. A + 1 D. is usually required to correct presbyopia at 45 years; 1 D. equals 100 cm. focal distance; the difference between 100 cm. and 22 cm. equals 78 cm., which is the range of vision in this case.

It should be remembered in prescribing glasses for presbyopes we require that his near-point with the glass (with at the same time the patient exerting his greatest accommodative effort) should be 22 cm. or eight inches. The natural reading distance is from 33 to 40 cm., 33 being the usual reading distance. This leaves the patient some reserve accommodative power; and Landolt claims that about one-third of the accommodative power should be held in reserve if the patient is to read or work comfortably; this even in young subjects. Landolt also asserts that about two-thirds of the converging power should be held in reserve for the patient to have comfortable fixation, and easy vision.

A patient at fifty years of age has accommodative power of about 2.50 D., or with all his accommodative effort exerted he can only read at 40 cm., or 16 inches. In order to read at 33 cm., or 13 inches, 3 D. of accommodation is required; and to read comfortably the patient should have ⅓ of this amount, that is 1 D., held in reserve. This 1 D. added to the 3 D. equals 4 D., and the difference between 4 D. and 2.50 D. (the amount of accommodative power possessed by the patient) equals 1.50 D. which is the strength of the glass that should be ordered for an emmetropic patient of 50 years of age.

Again, in ordering glasses for presbyopes the purpose for which they are wanted must be taken into consideration. For instance, for reading music, manuscript in the pulpit, playing cards, working at the bench, and occasionally for desk work the near-point should not be brought nearer than 20 to 24 inches.

Each eye should be tested separately as well as both together for the near-point, for occasionally it will be found that the accommodative power, even where no paralysis of the accommodation is present, is different in the two eyes. This difference may amount to as much as 1 D., and in ordering the glasses this inequality should be taken into consideration. Finally, it must be said that no hard and fixed rule holds for prescribing glasses in presbyopia. Each patient must be fitted with the glasses that give best vision at the distance desired for working. See, also, **Presbyopia,** p. 10357, Vol. XIII of this *Encyclopedia.*

Anisometropia and antimetropia.

Anisometropia, in its literal sense (from Greek, *anisos,* unequal; *metron,* measure, and *ops,* the eye) means unequal vision, and often is used to include the term *antimetropia* (Greek *anti,* opposed; *metron,* measure, and *ops,* the eye) though incorrectly so. In anisometropia the refractive error in the two eyes may be of the same nature, e. g., hypermetropic, but one eye more hypermetropic than the other; myopic, but one more myopic than the other; one eye emmetropic and the other hypermetropic or myopic.

Of course astigmatism may be a complicating factor in all these cases. In antimetropia one eye is hypermetropic, with or without astigmatism, while the other eye is myopic with or without astigmatism. See, in addition, p. 485, Vol. I of this *Encyclopedia.*

Aphakia.

Aphakia is that condition of the eye in which the crystalline lens is absent, and is most frequently the result of cataract extraction. It may result, however, from an accidental injury to the eye.

So far as the refraction of the eye is concerned the lens may not really be absent, but simply dislocated or displaced from the pupillary area, e. g., as in the old and first method of operating on cataract, *couching,* the lens was depressed below the pupil, down and backward into the vitreous. Again, the lens may be congenitally, by disease, or accidentally luxated or dislocated, so that it does not serve its function as a refractive medium.

The displacement may be incomplete or complete. But even in incomplete displacements, where the edge of the lens remains in the pupillary space, as often happens in congenital cases, the aphakic part of the pupil, as a rule, must be corrected, since the astigmatism at the edge of the lens (non-cataractous) is so great and irregular that suitable glasses cannot be found.

With the lens absent we have a true curvature ametropia present and the dioptric condition the simplest, and we have to deal with only the anterior convex surface of the cornea. The nodal point in this instance is at the center of curvature of the cornea. The refraction of an aphakic eye is usually hypermetropic in character.

Following cataract extraction in the emmetropic eye a + 10 D. to + 11 D. lens is required, and if the patient was hypermetropic beforehand the plus glass representing the hypermetropia must be added to this glass. On the other hand, should myopia be present, the glass representing the myopia must be deducted from the strong plus lens; that is, the sum of a — and a + glass. It might so happen that the myopia just neutralizes the operative hypermetropia, when the patient would require no lens for distant vision—a rare and fortunate condition. This is one of the advantages claimed for extracting the clear lens in high myopia. It must be remembered, however, that accommodative power is lost in these cases; and a more serious, though rare, complication of the operation is detachment of the retina which sometimes follows weeks, months or years after the operation.

As above stated the nodal point in an aphakic eye is situated at the center of curvature of the cornea, and when a strong plus glass is placed in front of the eye it moves the nodal point forward, and in this way the retinal images are enlarged, even more than they would be in an axial ametropia of like amount.

As would be supposed, the aphakic or lenseless eye, where the corneal astigmatism only has to be considered, is the ideal eye for the use of the ophthalmometer. Nevertheless the nodal point is moved forward by the removal of the crystalline lens, and hence, the cylinder being combined, almost without exception, with a strong spherical glass, which must be worn one-half inch in front of the eye, the strength of the glass necessary for the correction of the astigmatism is rarely ever as great as that indicated by the ophthalmometer, even though the astigmatism is against the rule. The same law for reduction in strength holds in regard to prescribing spherical glasses after cataract extraction. For example, say the amount of hypermetropia in an eye after cataract extraction is 11 D. Now, since there is no crystalline lens in such an eye, it would naturally seem that it would require a plus 11 D. (3½ inch) lens to correct this error, and, as a matter of fact, it would, could the glass be worn in contact with the cornea. But since the ordinary wearing distance of a glass from the eye is 12 to 14 mm., or about one-half inch, this moving forward of one-half inch perceptibly increases the strength of strong convex glasses, and, therefore, a reduction in strength must be made. In the present supposed example of 11 D. hypermetropia, instead of there being required a + 11 D. to correct it, a much weaker glass, when placed at the usual one-half inch wearing distance in front of the eye, will accomplish what is required. To be exact, it would require a glass of only 3½ in. plus ½ in. (the ½ in. being the distance in front of the eye that the glass is worn), which equals a four-inch focus glass; and a four-inch focus glass equals 10 D. By which it is seen that one whole diopter is deducted from the glass.

This increase in the power of convex glasses, brought about by wearing them ½ inch in front of the eyes, holds with normal as well as with aphakic eyes. However the glasses are usually so weak that the slight displacement of one-half inch does not make a great difference in their strength. There are exceptional cases where it does, but they are rare. In cataract cases, however, the glasses must be very strong, except when the eye has been strongly myopic before operation, and a slight change in position of the glass, as shown above, makes a big difference in its refractive effect. To give another example, say that the patient was hypermetropic 5 D. before the operation, and 16 D. after the operation, it is evident that if a plus glass of 16 D. (2½ in. focus) could be worn in contact with the cornea it would correct the 16 D. of hypermetropia; but, as it must be worn one-half inch in front of the eye, it must be reduced in strength. That is, it would require a glass of 2½ plus ½ = 3 in. focus, which equals only 13 D., a decrease in strength of three diopters.

The discrepancy in the reading of the ophthalmometer and the cylindrical glass accepted by the patient after cataract extraction is not because of an error in the reading of the instrument, but is to be ascribed chiefly to the great reduction in strength that has to be made in strong cylinders on account of the one-half inch distance at which they must be worn in front of the eye, especially so when combined with strong spherical glasses. For example, if we have an astigmatism of 3 D. against the rule, 180 degrees plus, and hypermetropia 10 D., the power of the glass to correct the error of refraction in the vertical meridian would be 13 D., and the horizontal meridian 10 D., if worn in contact with the eye. But they are one-half inch in front of the eye. A 13 D. glass has a 3 in. focus, plus ½ inch in front of the eye equals 3½ in. focus, equals 11 D. for the vertical meridian. For the horizontal meridian, 10 D. equals 4 in., plus ½ in. equals 4½ in. equals 9 D. The difference between 11 D. and 9 D., the glasses which respectively it requires to correct the vertical and horizontal meridians, on account of their position in front of the eye, is only 2 D., and, therefore, it would take but 2 D. cyl. to correct the 3 D. of corneal astigmatism. Again, take 6 D. of astigmatism, axis 180 degrees, with 10 D. of H. The vertical meridian would require 16 D. (2½ in.) to correct it, if worn in contact with the eye; 2½ in. plus ½ in. equals 3 in. equals 13 D., which glass it really takes. The horizontal meridian would take 10 D. (4 in.); 4 plus ½ equals 4½ in. equals 9 D. Now, 13 D. minus 9 D. equals 4 D., the amount of cylinder, axis 180 degrees, it takes to correct the 6 D. of corneal astigmatism!

Carl Weiland says: "Cases of aphakia are, therefore, the ideal field for keratometry, but owing to the high spheres usually necessary, there is a great difference between the correcting cylinder at 14 mm. from the eye and that in contact with the cornea, which latter, as we know, is given by Javal's instrument. The following table will show this at a glance, which is given for plus 10 D. for far, and plus 14 D. for reading.

Ophthalmometric Table.

A	△	Full Correction	A	△	Full Correction
+ 1	+ 10	+ 10 — .75 cyl.	+ 1	+ 14	+ 14 — .66 cyl.
— 1	+ 10	+ 10 + .73 cyl.	— 1	+ 14	+ 14 + .65 cyl.
— 2	+ 10	+ 10 + 1.45 cyl.	— 2	+ 14	+ 14 + 1.25 cyl.
+ 2	+ 10	+ 10 — 1.50 cyl.	+ 2	+ 14	+ 14 — 1.3 cyl.
— 3	+ 10	+ 10 + 2.1 cyl.	— 3	+ 14	+ 14 + 1.8 cyl.
— 4	+ 10	+ 10 + 2.8 cyl.	— 4	+ 14	+ 14 + 2.5 cyl.
— 5	+ 10	+ 10 + 3.50 cyl.	— 5	+ 14	+ 14 + 3.18 cyl.
— 6	+ 10	+ 10 + 4.1 cyl.	— 6	+ 14	+ 14 + 3.66 cyl.

"This shows conclusively the necessity of correcting in aphakia the keratomically determined cylinder for its position and for the coexisting axial condition, for even with a plus 1 D. it amounts to .25 D. and more, while for an astigmatism of 6 D. against the rule, it amounts to almost 2.50 D. At the same time, we observe that in the same individual the cylinder may be reduced perceptibly for reading. We also find that the numbers obtained by the keratometer are always too high, no matter whether the astigmatism is with or against the rule" (*Arch. of Oph.*, Jan., 1893). See, also, p. 4709, Vol. VI, and p. 8926, Vol. XII, as well as Section 34, Vol. XIII of this *Encyclopedia*.

CHAPTER V.

THE DIFFERENT FORMS OF AMETROPIA AND THEIR CLINICAL SYMPTOMS. SYMPTOMS.

Hypermetropia.

The clinical forms of hypermetropia are two—(1) manifest, (2) latent; the sum of the two being the total hypermetropia.

Manifest hypermetropia is ascertained by placing plus glasses of increasing strength before the eyes until the strongest glass which gives the best vision for the distance (20 feet or more) is reached; e. g., say, a patient accepts plus 2 D. in each eye and the vision is brought up to 20/20, 2 D., is the amount of manifest hypermetropia present. But say that in the eyes of the same patient a cycloplegic is used (atropine sulphate, one per cent. solution) and the patient accepts a plus 4 D. in each eye and still sees 20/20, this 4 D. is the total hypermetropia; and the difference between the total and the manifest shows the amount of the *latent* hypermetropia present. In this case it is the difference between 4 D. and 2 D., or 2 D.

Manifest hypermetropia is subdivided into *facultative* and *absolute;* the facultative being that part which the patient can correct by using the ciliary muscle, while the absolute is that part of the manifest that can not be corrected by the use of the ciliary muscle and requires a plus glass to bring out the best vision. To go back to the example above given of 4 D. of total hypermetropia, by way of illustration. In this example 2 D. of the hypermetropia present is manifest. We will assume that the patient without any glass saw 20/40, and it required plus 1 D. to enable the patient to see 20/20; this first 1 D. would be the *manifest absolute* hypermetropia, since the patient could not correct this part of the hypermetropia with accommodative effort, but required plus 1 D. glass to bring up the vision to 20/20. The patient, however, accepted another plus 1 D. which maintained his vision at 20/20, and this last 1 D. represented the *manifest facultative* hypermetropia, the patient in this instance being able (having the faculty) to correct with the ciliary muscle the 1 D. of hypermetropia, if he chose. In other words the absolute manifest hypermetropia is that part which the patient cannot correct by using the ciliary muscle, while facultative manifest hypermetropia is that part which he can correct by the use of the ciliary muscle by accommodative effort. In the above example the

absolute manifest = 1 D.
facultative manifest = 1 D.
latent = 2 D.

Total = 4 D.;

and these are the different varieties of hypermetropia with which we have to deal.

In young subjects the latent hypermetropia is greater, as compared with the manifest, than in older subjects, being greatest at about ten years of age and gradually diminishing until at the age of fifty-five or sixty, as a rule, all the latent hypermetropia has become manifest. Not only that, but the facultative manifest has become absolute; in other words at about sixty years of age accommodative effort is nil and the hypermetrope must have glasses to see distinctly, even for the distance. Also in young subjects with high degrees of hypermetropia, generally a considerable amount of the hypermetropia is latent, and of the manifest most of it may be facultative, with only a small part of it absolute. This latter must be corrected if the patient expects to see distinctly. Furthermore, if the patient is to see distinctly and without effort the facultative manifest hypermetropia must be corrected also, and often part of the latent hypermetropia. In low degrees of hypermetropia (1 to 2 or 3 D.) in young subjects, and where no astigmatism is complicating, the patient often prefers to go without glasses, the accommodative effort being sufficient to overcome the hypermetropia and render the eye emmetropic both for distance and near work.

Donders' description of the clinical symptoms of hypermetropia holds today, and but little need be added to it. However, in this modern-day stress of life, and especially with the strain put upon the eyes in the schools and factories, the symptoms of hypermetropia —blurring of vision, pains in the eyes and temples, headaches, and inability to continue the use of the eyes for long periods of time—are more pronounced than in Donders' time. At least we often come in contact with patients suffering with just such symptoms as he describes. In young subjects unless the hypermetropia is of high amount or complicated with astigmatism, the patient, if in good health, is able to use the eyes with entire comfort and without fatigue. But as the presbyopic period of life approaches, even in simple uncomplicated hypermetropia the symptoms of asthenopia appear and glasses must be worn. In weak or debilitated subjects with hypermetropia, glasses must be worn earlier, at any rate for near work and reading.

Parents often have a pardonable prejudice against glasses for the young, and frequently ask if glasses do not weaken the eyes, and also if glasses once put on will they not have to be kept on, and if glasses will not actually do the eyes harm if begun too early? To all such inquiries we answer that if the child is really in need of glasses as is manifested by the symptoms, glasses will not injure the eyes but benefit them; not only that but the general health is often improved by their use. Furthermore, we advise that by the general improvement in health the child may be able to give up the glasses for distance vision and perhaps for near work after a time. But should he not be able to give up the glasses, without return of the symptoms, then they should be worn all the time. It should be remembered also that hypermetropes when approaching the presbyopic age are driven to wear glasses for the near-point earlier than emmetropes, due to the excessive strain put upon the accommodation, and this even with the ciliary muscle being slightly stronger in hypermetropes than in emmetropes.

In hypermetropia not only may we have asthenopic symptoms present but a squint may and often does develop from the extra strain put upon the accommodation. And this condition may be, and often is, relieved by the use of the proper correcting glasses, if the patient is seen early enough after the squint develops. Occasionally, in very high degrees of hypermetropia, the patient not being able to hold the print far enough from the eyes to obtain a distinct image, reverses the processes and holds the print very close to the eyes. In this way images are rendered less distinct but much larger, and the patient interprets them much more readily, especially if he partially closes his eyelids, as is often done in high degrees of myopia; or, if he holds the print in a bright light which at the same time shines in his own eyes contracting the pupils he sees more clearly. The partially closed eyelids and the small pupil serve to cut off the most peripheral rays, thus rendering the images more distinct, and as the more central rays form less diffused images than the peripheral ones the patient sees fairly well. Other symptoms of hypermetropic refraction are: redness of the edges of the eyelids (blepharitis marginalis), styes, conjunctivitis. Even retinal irritation may develop if the eyes are used too much without the proper correction of the hypermetropia. Also nervous symptoms, as twitching of the eyelids or muscles of the face may develop; and some distinguished authorities claim that general nervous affections, as epilepsy, chorea, etc., may develop from eye-strain, especially the eye-strain of hypermetropia with astigmatism and muscle imbalance as complicating factors. However this may be, we know that hypermetropia is often the source of much discomfort to the patient and that correcting glasses are a means of relief. See, also, **Hypermetropia,** p. 6096, Vol. VIII of this *Encyclopedia.*

Clinical myopia.

The clinical forms of myopia are two: *axial myopia,* where the eyeball is too long, and *curvature myopia,* where either the cornea or the crystalline lens, or both, are too sharply curved. There is a so-called pseudo- or false, myopia, due to spasm of the accommodation.

In certain diseased conditions of the eyes, as conical cornea, very high myopia with irregular astigmatism obtains; and again in eyes with diffuse opacities of the cornea, myopia, even of the axial type, may be produced. This latter is brought about in a measure perhaps by the patient holding the print or fine work close to the eyes to enlarge the images of the objects to obtain better vision; and in doing so the external recti muscles are forcibly stretched over the temporal side of the eyeballs, thus lengthening the globe.

Symptoms: Unlike hypermetropia, myopia, unless complicated with astigmatism or is of high degree with pathologic changes in the fundi, rarely gives rise to asthenopic symptoms, that is, headaches, pains in the eyes, and a tired feeling about the eyes, so common in hypermetropia.

Astigmatism may complicate all degrees of myopia, while pathologic changes in the choroid and retina are most common in the higher degrees of myopia. In these latter cases vision is poor not only because of the myopia but on account of the diseased condition of the choroid and retina. Moreover, the strain put upon these eyes to secure better vision often congests them, and renders them painful to light; again, because of the very near point at which such eyes must be used an extra strain is put upon the convergence, producing asthenopic symptoms even in eyes which have no pathologic changes.

Muscæ voltitantes are a common symptom of high myopia, and, when the choroid and retina are involved, often large opacities and shreds are present in the vitreous to add to the annoyance and fear caused by such specks floating in front of the eyes. Again, because of the fact that the point of distinct vision in myopes of high degree is only a few inches in front of the eyes, distinct single binocular vision is often out of the question, and the patient, being able to keep the two eyes fixed on the object, allows one eye to swing out of the line of vision and a divergent squint results, a not infrequent accompaniment of high myopia.

The ophthalmoscopic symptoms of myopia are characteristic, especially in the higher grades thereof. In the lower and moderate grades (from 1 to 4 diopters), the fundus conditions often differ in no particular manner from the fundus of the emmetropic or moderately hypermetropic eye, except that the optic nerve appears a little larger. However, in the higher grades of myopia not only is the optic disc apparently enlarged (from the increased refractive power) but at the temporal side often there is a white crescent (the myopic crescent) due to atrophy of the choroid at this point.

Frequently shreds of membrane and opacities are to be observed floating in the vitreous, and the vitreous itself may become rarefied and fluid. If the choroid is very extensively involved, and particularly if the retina becomes detached, a complicating cataract may develop.

The objective symptoms of myopia are, prominence of the eyes, relatively wide pupils, objects are held much too near the eye, and there is a tendency for the patient to close the eyelids almost together when trying to see distinctly.

The prominence of the eye is due to the lengthened eyeball, while the wide pupils are the result of relaxation of the accommodation and incidentally of the convergence of the eyes. The squinting of the eyelids together is to cut off the peripheral rays from entering the eye, thus securing a better image on the retina of the elongated eyeball. It is from this squinting of the eyelids together, which so often obtains in myopia, that the name originates.

A peculiarity in some cases of myopia of moderate degree is that they are unaware that they see less distinctly than people with normal vision; and are brought to a realization of this defect in their vision only after having had glasses prescribed, the contrast between the improved vision and the former poor vision then being possible.

Glasses have a very favorable influence on myopia if prescribed in the early stages, and the myopia should be fully corrected, up to as high as 6 or 8 D. Usually patients will not tolerate a full correction if the myopia is higher than 6 or 8 D. However, if the myopia has been fully corrected from the first and the glasses increased in strength as the myopia increased, patients will at times wear full correction up to 10 D. or 12 D. in amount for all distances, that is, constantly.

In myopia of high degree, 10 D. and over, some reduction in the strength of the glass for the near-point must be made. A good theorctic rule is to find the full correction for the distance, then deduct from this glass the number of diopters that is obtained by dividing the number of inches at which the patient desires to work, read, or sew, etc., into 40 inches (the number of English inches to the meter) and the quotient will be the number of diopters to subtract from the distance glass. For example, say the patient accepts a — 14 D. for the distance, and desires a reading glass to enable him to read at 13 inches; thirteen into forty will go 3 times, and a fraction over. This represents in diopters the amount to be subtracted from the distance glass 14 — 3 = 11 D., the latter being the glass the patient should wear for near work. Often, however, in the higher degrees of myopia more than the amount obtained in this way must be deducted from the distance glass. As a matter of fact, frequently the distance glass must be reduced in strength if the patient is to have *comfortable* vision, though not so clear vision results as can be obtained with full correction. In the higher grades, as a rule, and often in the lower grades, of myopia a greater or lesser degree of insufficiency of the internal recti muscles obtains. If of considerable amount this adds to the difficulty of single binocular vision. Furthermore, the shape of the eye itself, the elongation which occurs in the higher degrees of myopia, adds to the trouble, as the antero-posterior axis of the eye assumes more or less nearly the axis of the orbit, the inward excursions of the eye especially being retarded.

Again, since the angle alpha in high degrees of myopia is very small, nil, or even negative (that is, the visual line cuts the cornea near its centre, or even to outer side of its centre) it requires the eye to be further converged to obtain single binocular vision than would be the case in H. where the angle is positive. All these points should be borne in mind when ordering and adjusting glasses for myopes.

In myopia, as a rule, the P. D. should be made a little wider than the actual pupil distance, especially if there is an insufficiency of the internal recti muscles.

Of course the common hygienics of vision should be insisted on in these cases, especially as to good light, not too long periods of use, and the patient should not read while lying down. Good print properly spaced is an important factor in preventing undue strain upon the eyes. In school-children particularly should the above directions be carried out; and the further precaution of having the student sit in an erect position when studying should be insisted upon. It goes without saying that suitable desks should be supplied for the students' use. See, also, the **Myopia** captions, beginning with p. 8265, Vol. XI, and Section VI of **Physiological optics** in this *Encyclopedia*.

CHAPTER VI.

ASTIGMATISM. ASTIGMIA.

The clinical varieties of astigmatism. For clinical purposes astigmatism (astigmia) may be considered under five types of the *regular* form, and under two types of the *irregular* form.

The varieties of *regular* astigmatism are: (1) hypermetropic simple; (2) hypermetropic compound; (3) myopic simple; (4) myopic compound; and (5) mixed. All these types may be situated either in the cornea or in the lens.

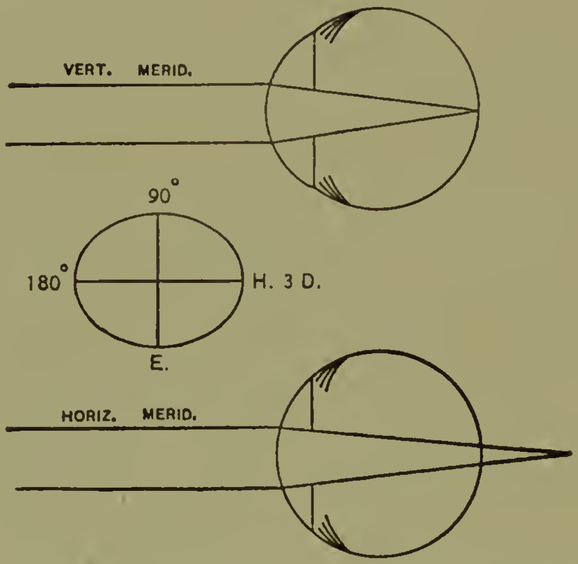


Fig. 13. Simple Hypermetropic Astigmatism with the Rule.

The two varieties of *irregular* astigmatism are: (1) irregular corneal; (2) irregular lenticular.

All the forms of regular astigmatism may be further divided into two general types: astigmatism *with the rule* (direct) and astigmatism *against the rule* (indirect or inverse).

When the axes of the astigmatism are at 45 degrees and 135 degrees, or in that neighborhood, the astigmatism is often designated *oblique*.

Because of the confusion often present in the minds of beginners, and also even in the minds of men of considerable experience, about astigmatism *with the rule* and astigmatism *against the rule,* a brief explanation of the meaning of the terms is in place here.

Astigmatism with the rule. This is the condition in which the vertical meridian of the cornea, or any meridian in the neighborhood of the vertical meridian, that is, within 4 or 5 degrees of the vertical, *is more curved* (of greater refractive power) than the meridian at right angles to it. We here speak of the corneal refraction.

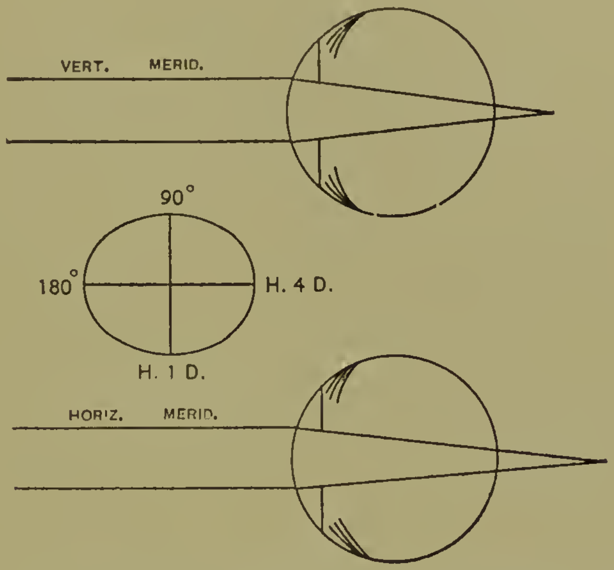


Fig. 14. Compound Hypermetropic Astigmatism with the Rule.

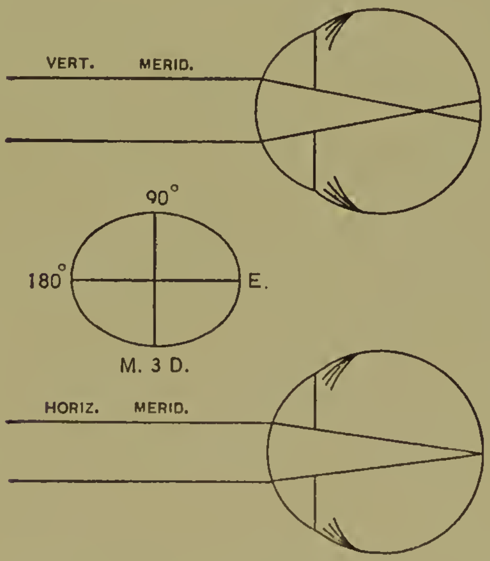


Fig. 15. Simple Myopic Astigmatism with the Rule.

Astigmatism against the rule. This is the condition where the vertical meridian of the cornea, or any meridian in the neighborhood of the vertical meridian (within 4 or 5 degrees of the vertical), *is less curved* (of less refractive power) than the meridian at right angles to it.

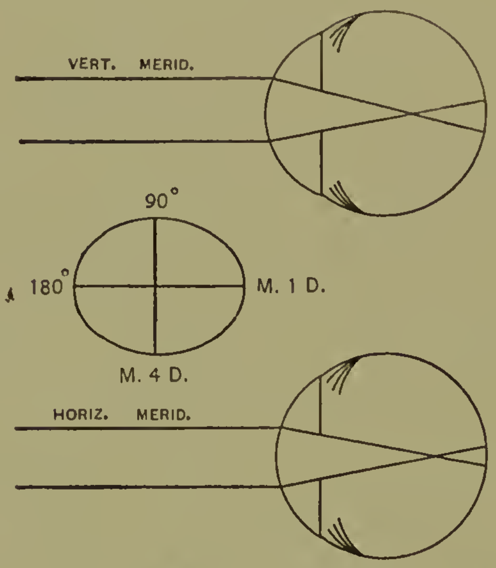


Fig. 16. Compound Myopic Astigmatism with the Rule.

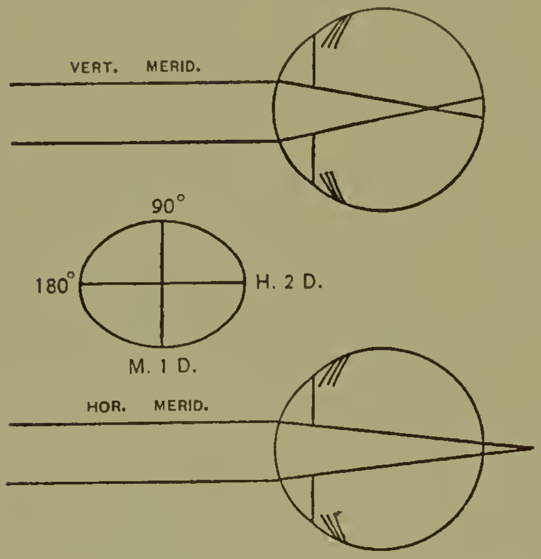


Fig. 17. Mixed Astigmatism with the Rule.

The vertical meridian of the cornea, or one in the neighborhood of it, in 75 to 80 per cent. of all cases of astigmatism in young and middle-aged subjects, gradually decreasing as age advances to about 30 per cent. of cases (Bennett and Clemensha, *Amer. Medicine*, Aug. 1, 1903), is more curved than the horizontal, or the meridian at right angles to it, and the astigmatism in such cases, as above stated, is said to be according to the rule, or, "with the rule."

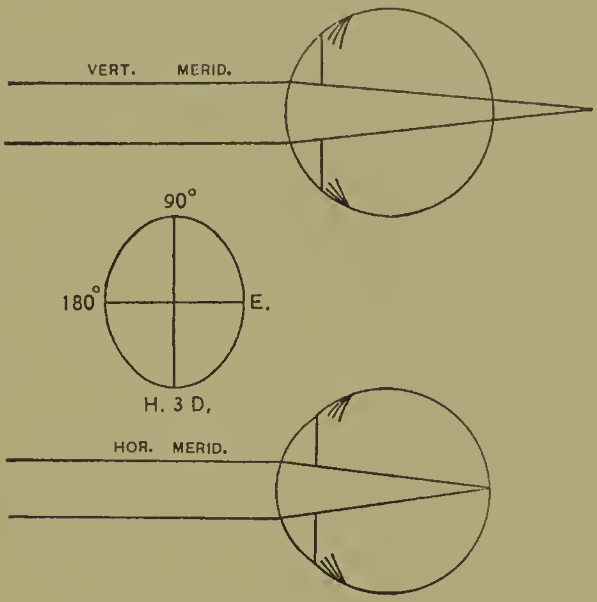


Fig. 18. Simple Hypermetropic Astigmatism Against the Rule.

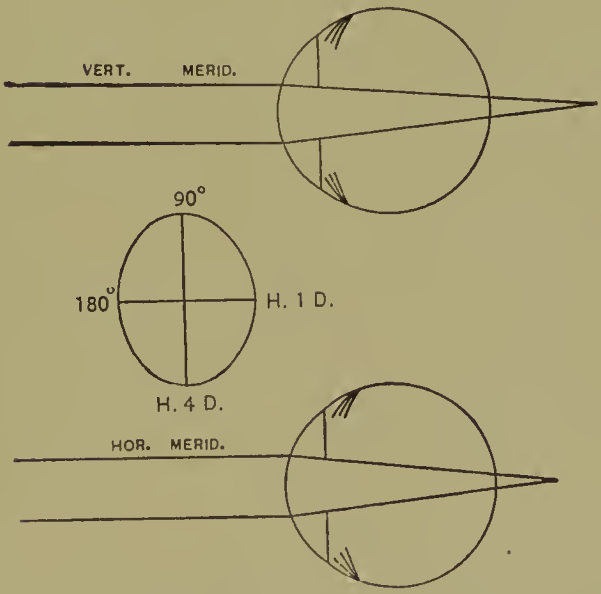


Fig. 19. Compound Hypermetropic Astigmatism Against the Rule.

Many times beginners ask if hypermetropic astigmatism is not always with the rule, and if myopic astigmatism is not always against the rule. As a matter of fact, it makes no difference whether the astigmatism be hypermetropic (simple or compound), myopic (simple or compound), or even mixed, as long as the vertical meridian of the cornea, or one within 4 or 5 degrees of it, is more curved than the meridian at right angles to it—that is, astigmatism with the rule.

Forms of astigmatism illustrated by diagrams. In order that the reader may not possibly go astray on this point we will take an example of each form of astigmatism, and show by diagrams how it may be "with the rule" in every form.

(1) Simple hypermetropic astigmatism with the rule. Fig. 13 shows the vertical and horizontal sections of an eye with such an error of refraction. It is seen by this diagram that the vertical meridian is emmetropic and allows the rays of light to focus on the retina, and is more curved than the horizontal meridian which is flat and allows the rays of light to focus back of the retina. Therefore, according to our definition of astigmatism with the rule, this must be a case of it, for the vertical meridian is more curved (of greater refractive power) than the horizontal.

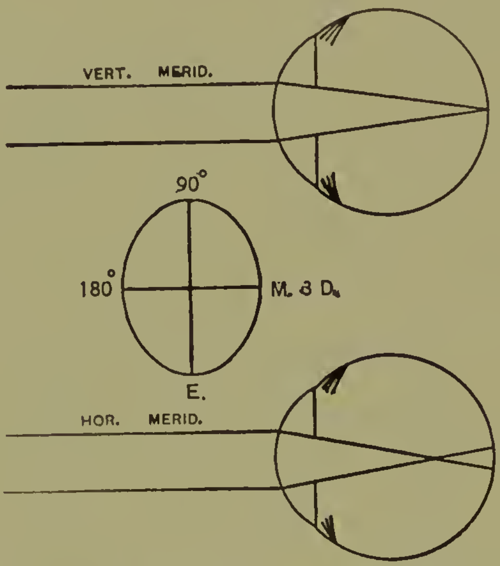


Fig. 20. Simple Myopic Astigmatism Against the Rule.

(2) Compound hypermetropic astigmatism with the rule. In such a case the vertical meridian is flat and allows the rays of light to focus back of the retina, but it is not as flat as the horizontal meridian which allows the rays to focus still farther behind the retina. Here again the vertical meridian is more curved than the horizontal, and, of course, the astigmatism is with the rule, though it is compound hypermetropic (see Fig. 14).

(3) Simple myopic astigmatism with the rule. Here the vertical

meridian is myopic, causing the rays of light to focus in front of the retina, and is more curved than the horizontal meridian, which is emmetropic, and allows the rays to focus on the retina. Now, this

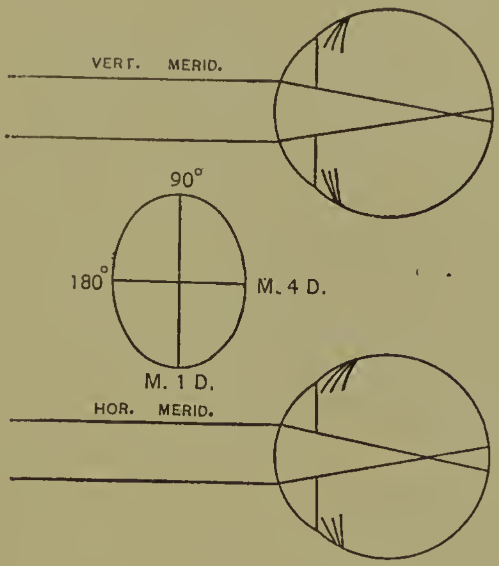


Fig. 21. Compound Myopic Astigmatism Against the Rule.

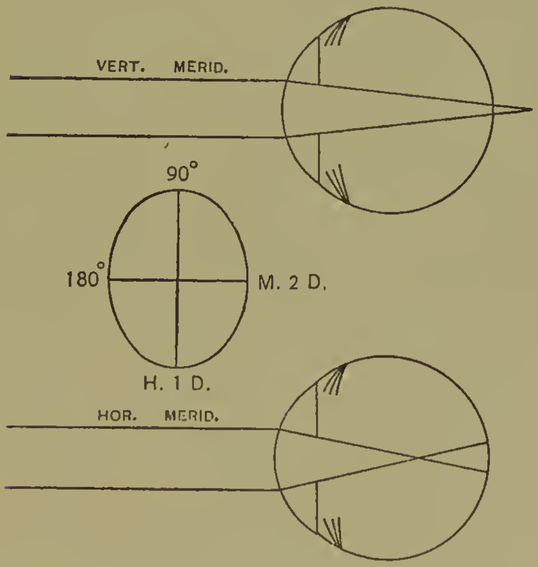


Fig. 22. Mixed Astigmatism Against the Rule.

is with the rule, though it is myopic astigmatism—simply because the vertical meridian is more curved (of greater refractive power) than the horizontal (see Fig. 15).

(4) Compound myopic astigmatism with the rule. The vertical

meridian is more myopic and at the same time more curved than the horizontal meridian, which latter fact makes it astigmatism with the rule (Fig. 16).

(5) Mixed astigmatism with the rule. The vertical meridian is myopic and focuses rays of light in front of the retina, and is more curved than the horizontal meridian which is hypermetropic (flat, less curved), and focuses rays back of the retina. The astigmatism is with the rule, therefore, though mixed (Fig. 17).

We see, then, by the above five diagrams that astigmatism may be with the rule in all of its forms; the only thing necessary to have it such, the *sine qua non,* so to speak, is that the vertical meridian of the cornea, or one in its neighborhood, shall be more curved than the horizontal or the one at right angles to it.

(1) *Simple hypermetropic astigmatism against the rule.* The vertical meridian is hypermetropic, focuses rays of light back of the retina, and is less curved than the horizontal meridian, which is emmetropic, and focuses rays on the retina (Fig. 18).

(2) *Compound hypermetropic astigmatism against the rule.* Here both meridians are hypermetropic, but the vertical more so than the horizontal, consequently the vertical meridian is less curved than the horizontal. The astigmatism is, therefore, against the rule (Fig. 19).

(3) *Simple myopic astigmatism against the rule.* The vertical meridian is emmetropic, focuses the rays on the retina, and is less curved than the horizontal meridian, which is myopic and focuses in front of the retina (Fig. 20).

(4) *Compound myopic astigmatism against the rule.* Here both meridians are myopic, but the vertical is less myopic than the horizontal, is less curved, and consequently it is astigmatism against the rule (Fig. 21).

(5) *Mixed astigmatism against the rule.* The vertical meridian is hypermetropic, focuses rays back of the retina, and is less curved than the horizontal meridian, which is myopic, and focuses rays in front of the retina (Fig. 22).

By the above diagrams we see that astigmatism may be against the rule in all its forms. So long as the vertical meridian of the cornea is less curved (of less refractive power) than the horizontal, that is astigmatism against the rule.

Some writers prefer to designate astigmatism as "direct" and "indirect."

We have gone very particularly and minutely into this point of astigmatism with the rule and against the rule, because we find in teaching that it is a point on which most beginners are in doubt. Some authors are inclined to attach but little importance to it, but the present writer has found it of much value in instructing. Because, if, on finding astigmatism with or against the rule you can teach the student to picture in his "mind's eye," so to speak, the condition of curvature of the cornea and the position of the focal points of its two chief meridians of curvature in relation to the retina in the various forms of astigmatism, it greatly assists him in adjusting glasses. In fact, it makes him think of the eye under observation, and not of some abstruse rule in the text-book.

Axes of regular astigmatism.

In regular astigmatism the chief meridians, that is, the meridian of maximum and the meridian of minimum refraction, are usually at right angles to each other, though not always, as stated by some authors (Hartridge and others). That the chief meridians are not *always* at right angles to each other may be easily ascertained by the use of the ophthalmometer.

Occasionally it will be found that the *secondary* position is not at right angles to the *primary* as found by the instrument, but varies from five to ten or fifteen degrees. For example, say the primary position is found to be 0 degrees or 180 degrees, that is, horizontal, and when the arc of the instrument is turned to 90 degrees, the second position, which is at right angles to 180 degrees, the *lines* dividing the mires are not coincident and straight with each other, and only become straight when the arc is turned to 95 or 100 degrees, or maybe to 85 degrees or 80 degrees, etc., indicating clearly that the second chief meridian is not at right angles to the first.

Such cases are rare, and even then the axes are so little off the right angle position that the variation may, in most cases, be neglected from a clinical standpoint.

Symmetry of the axes of astigmatism obtains in a large percentage of cases, that is, the chief meridians lie in corresponding positions in the two eyes; for example, exactly at 90 degrees and 180 degrees, or the same number of degrees from the vertical, each to the temporal or the nasal side, as at 105 degrees right, and 75 degrees left, or vice versa; or at 15 degrees or 165 degrees, that is, the axes are inclined to lie in symmetrical meridians. (Snellen, Graefe *Arch. f. Oph.*, Vol. XVI, No. 2, p. 200, 1869; also Knapp, *Trans. Amer. Oph. Soc.*, Vol. VI, p. 308, 1892, as well as Claiborne, *New York Med. Journal,* June 25 and July 2, 1892, and *Annals of Oph.*, July, 1909.)

When the chief meridians do not lie in corresponding meridians in the two eyes, the astigmatism is said to be asymmetrical, while if the chief meridians slant consensually, that is, in the same direction, and to the same distance from the vertical meridian, the axes are asymmetrical and homologous, e. g., say the meridian of greatest refraction in each eye is at 75 degrees.

The axis of the astigmatism following cataract extraction is usually parallel with the direction of the incision in the cornea, the more refractive meridian parallel with, and the lesser refractive meridian perpendicular to, the incision. Since the wound is usually made above, the astigmatism is usually against the rule, that is, the least refracting meridian is at, or near, 90 degrees. Both the amount and the axis of the astigmatism change considerably in the first few weeks following cataract extraction, hence glasses, unless temporary, should not be prescribed in such cases for at least six or eight weeks following the operation, and it is better to wait even longer, three or four months, to get the best results with glasses.

In *irregular* astigmatism, as a rule, but little improvement is to be expected from the use of glasses. However, in those cases of irregular astigmatism where there is at the same time a large amount of *regular* astigmatism, vision may be very considerably improved by correcting the regular part of the astigmatism. This is a point often neglected, the case being considered beyond help, and the patient allowed to go without correction which he might have and ought to have given him. Much patience on the part of the surgeon is required in such cases, but with persistence a very considerable improvement in the vision is sometimes obtained.

CHAPTER VII.

APPLIED REFRACTION.

The use of mydriatics and cycloplegics.

A distinction is to be made between mydriatics and cycloplegics, although the drugs representing both agents are often included under the one term—mydriatics.

A mydriatic drug *dilates* the pupil, and has but little or no effect on the accommodation. Euphthalmin and cocain are the best examples.

A cycloplegic *paralyzes the accommodation* and in addition it dilates the pupil, so having a double effect, "cycloplegic," and "mydriatic." Atropin sulphate and scopolamin hydrochlorate are the most effective. There are drugs also that give full mydriatic effect, but possess only partial cycloplegic action, the best example of which is homatropin hydrobromate. Many surgeons claim full cycloplegic action for this drug when used in cumulative instillations, as is the custom in most instances.

It is the practice of most ophthalmic surgeons in correcting errors of refraction to make use of a mydriatic or a cycloplegic in all patients (with few exceptions) under forty years of age; and some surgeons, sorry to say, frequently use cycloplegics in older subjects. In other words, the rule is to use cycloplegics in patients under forty years of age, and the exception is not to employ them.

The writer's individual practice is just the reverse of this, that is to use a cycloplegic is the exception.

In patients over forty years of age he almost never uses a cycloplegic and only occasionally a mydriatic for fundus examination.

In patients under fourteen years of age, in strabismus patients, in all patients where the vision cannot be brought to near the normal, or where a fundus lesion is suspected it is the writer's practice to use a mydriatic or a cycloplegic, but otherwise not. That is to say, it is the exception and not the rule to make use of cycloplegics.

It is believed that fewer surgeons now than formally resort to the old routine method of using cycloplegics in every case of refraction, presbyopes excluded, being content to use simple mydriatics (as cocain and euphthalmin), or, as is more commonly the case, the pseudo-cycloplegic, homatropin, either singly or in combination with cocain, in most cases; true cycloplegics, as atropin sulphate, being reserved for exceptional cases of spasm of the ciliary muscle.

Where skiascopy is depended on chiefly as the objective test, cycloplegia or at least mydriasis must be had in order to use the test for astigmatism to the best advantage. But this is not the case with keratometry, for here the test for astigmatism can be as well made without a mydriatic as with it.

Of course subjective tests must be made in all cases where the patients are capable of responding to them.

In difficult cases one should employ all of the objective tests—keratometry, phakometry, skiascopy, and the ophthalmoscope, together with the subjective tests, and in addition use a real cycloplegic, atropin or scopolamin.

The chief reason for the lessened use of cycloplegics in testing for errors of refraction has been brought about by the improved objective method (keratometry) of measuring the amount and axis of the corneal astigmatism; and also in the last few years, through the improved objective method of measuring the lenticular astigmatism (phakometry) by means of Souter's improved and practical instrument the ophthalmo-phakometer. This instrument is constructed on the same principle as that of Tscherning, but has been made a practical office instrument.

With these two objective methods for measuring astigmatism, which is the most important problem in correcting errors of refraction, there will be even less call for cycloplegics, in the writer's opinion, in refractive work.

[As just stated by the writer, this is *not*, however, the opinion expressed nor the procedure adopted by the majority of American ophthalmologists who are authorities on this subject. See, for example, de Schweinitz (*Diseases of the Eye*, 7th Ed., p. 150); Duane (Fuch's *Text-Book of Ophthalmology*, Fifth Edition, p. 901); Weeks (*Treatise on Diseases of the Eye*, p. 682) and Ball (*Modern Ophthalmology*, Fourth Ed., p. 733). Edward Jackson (*Manual of Diseases of the Eye*, p. 127) sums up the arguments and gives the indications for the employment of cycloplegics and mydriatics in measuring refractive errors in these words: "The use of a cycloplegic is necessary whenever it is desired to make a complete study and accurate measurement of the refraction in a patient under fifty years of age. Without it the refraction can be guessed at, often correctly." See, also, **Cycloplegic**, p. 3641 Vol. V, of this *Encyclopedia*.—Ed.]

Before instilling a cycloplegic or a mydriatic into the eye of an adult the tension should be taken. If there is any increase of tension mydriatic drugs must not be used. After using mydriatics and cycloplegics it is a good plan to instill a drop of a one per cent. solution of pilocarpin, or a drop of one-fifth of one per cent. solution of eserin into the eyes. This diminishes the danger of inducing glaucoma, and also contracts the pupil, thereby lessening the discomfort of the patient.

The following are the chief mydriatic and cycloplegic drugs used in ophthalmic practice.

Atropin sulphate. This is most commonly used in a solution 4 grains to the ounce, for adults, and one-half to one-fourth that strength for children, the instillations being made by the cumulative method, or extending over days, as the surgeon prefers and the patient can arrange for.

One drop of such solution instilled into the eyes, consecutively, 10 minutes apart, for forty minutes will, as a rule, produce complete paralysis of the accommodation at the end of two hours from the time the instillations were begun, when the test for glasses may be made.

In children and patients not pressed for time, one drop of the solution instilled into the eyes three times a day for two or three days usually accomplishes full paralysis, though, in exceptional cases, it may be required to extend the use of the drops over several days or a week.

The effect of the drug on the accommodation and the pupil does not pass off until a week or two weeks, according to the number of instillations made.

Scopolamin hydrobromate is a powerful cycloplegic employed in a solution, 2 grains to the ounce, for adults and half that strength for children. Used in the cumulative method (one drop every ten minutes for forty minutes) it produces complete paralysis of accommodation in one hour from the first instillation.

In the author's experience one-half the strength as advised above, has been found effective. Quite distressing symptoms follow at times and it should be used most carefully. Its effects wear off in three or four days—less than one-half the time required following atropin cycloplegia, which is of advantage. Furthermore, it is claimed by Raehlmann that it does not increase the tension of the eye. This latter point, however, has not been fully established.

Hyoscyamin sulphate in a solution of two grains to one ounce, used as atropin by the cumulative method, causes complete cycloplegia in about one hour's time. Its effect wears off in 6 to 8 days.

Duboisin sulphate in solution of 4 grains to 1 ounce, used by the cumulative method, produces complete cycloplegia in about one hour's time. The effect wears off in from 6 to 7 days. This drug should be used with care as its toxic properties are strong, and it may cause distressing symptoms.

Daturia sulphate in solution, 2 grains to the ounce, used by the cumulative method, produces complete cycloplegia in about one hour. Its effect wears off in 8 to 10 days.

Homatropin hydrobromate may be classed as a partial or pseudo-cycloplegic. Where there is a tendency to spasm of the accommodation it is not effective and is not to be relied upon. It should be used in solution, 12 to 15 grains to the ounce, by the cumulative method, one drop every ten minutes for one hour. At the end of two hours from the first instillation its maximum effect on the accommodation is exerted, and the test for glasses may be begun. Many surgeons combine the use of cocain (2 to 4 per cent. solution) with that of the homatropin; or combine the cocain and homatropin in tablet form, and are of the opinion that the cycloplegia is made more complete by this method (Casey Wood).

Opposed to this view of the combination of homatropin and cocain, de Schweinitz regards "the addition of cocain to the solution as a distinct disadvantage."

After the use of homatropin, the patient should have a drop of a 1 per cent. solution of pilocarpin, or eserin solution, 1 grain to the ounce, instilled into the eyes before he leaves the office. Plain smoked glasses should be worn until the effect of the drug has disappeared, which requires about 48 hours.

Mydriatics.

Cocain muriate in 4 per cent. solution is the most widely used mydriatic. One drop of the solution instilled into the eyes and repeated in five minutes will produce mydriasis in twenty minutes' time. If the strength of the solution is increased or if the 4 per cent. solution is used too frequently it causes desquamation of the corneal epithelium and prevents a clear view of the fundus. A 4 per cent. solution of cocain used in combination with a weak solution of homatropin (2 grains to one ounce) effects a quick and almost complete mydriasis in fifteen or twenty minutes. After the examination is made, to lessen the discomfort of the patient, one drop of one per cent. solution of pilocarpin muriate should be instilled into the eyes. Drying of the corneal epithelium by the cocain may be prevented if the patient will keep his eyes closed most of the time while waiting for the mydriatic effect of the drug.

Euphthalmin in five per cent. solution, used after the manner of cocain solution, produces wide mydriases in twenty minutes. If combined with one drop of a four per cent. solution of cocain, the effect is both quickened and increased. After using it, pilocarpin should be instilled before the patient leaves the office.

The different methods of measuring refractive errors.

Subjective tests. The chief subjective test is that made with the test-types of Snellen, or with broken circles (Landolt, Jackson), or, in cases of illiterates and children, with figures or drawings of familiar objects.

For ascertaining the axes of astigmatism, the various astigmatic charts, Green's, Wallace's (p. 2297, Vol. III), Verhoeff's (p. 4740, Vol. VI) and others; and astigmatic letters (Pray's, p. 10334, Vol.

XIII; as well as p. 2012, Vol. III of this *Encyclopedia*). The cross cylinder and astigmatic lens (Jackson) are used. See p. 4641, *et seq.*, Vol. VI of this *Encyclopedia.*

Visual acuteness. The acuteness of vision is the function of the nervous structure of the retina (chiefly the macular region) and is concerned in the perception of the form and size of objects. It was with the object of having a uniform or standard test for the acuteness of vision that Snellen made his test-types. He constructed his test-letters so that each stroke of the letter subtends an angle of one minute, and the whole letter subtends an angle of five minutes. See **Examination of the eye,** p. 4641, Vol. VI of this *Encyclopedia.*

The ability to distinguish letters subtending such angle (5 minutes) according to Snellen represents normal acuteness of vision.

As the *visual angle* is the angle formed between the two lines drawn from the opposite extremities of an object to the nodal point of the eye, at which point the lines cross and continue to the retina, without deflection, it is apparent that the farther removed the object the larger must it be in order to be seen. The length of the eye itself also has a bearing on the size of the image of an object falling on the retina. The image of an object situated at the same distance in front of a hypermetropic eye will be smaller than for an emmetropic eye, and in turn the image for the emmetropic eye will be smaller than that for a myopic eye.

However, if the refractive error be corrected, the same sized object will be seen the same distance from the eye, provided of course, that the perceptive power of the eyes is the same. When the object is removed to such a distance that the visual angle is so small that the retinal images of the object cannot be perceived, the limit of perception has been reached. The anatomic structure of the retina has a bearing on the limit of perception, as it has been found by experiment that the *shortest distance* between two points on that membrane which can be perceived is about 0.00433 mm., that is, equals about twice the diameter of a retinal cone. At the macular region the cones are smaller in diameter, about 0.0033 mm., or even 0.002 mm., consequently, in this region smaller retinal images can be perceived than at the periphery of the retina, assuming that each cone is capable of perceiving a point of light. Images of smaller diameter than 0.002 mm., therefore, cannot be distinguished, even at the macular region.

Tests for the acuteness of vision.

The most common test-letters employed for testing the acuteness of vision are those of Snellen. The test card should be hung at a distance of six metres (approximately 20 feet) and should be well illuminated, preferably by artificial light, as this is uniform in intensity.

The distance of six metres or 20 feet is considered infinity, and rays of light coming from this distance are assumed to be parallel when they reach the eye. As a matter of fact they are slightly divergent, but the resultant error (requiring about 1/6 D. glass, as expressed in diopters, to render them parallel) may be disregarded in practice.

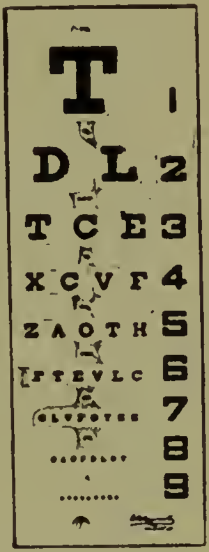


Fig. 23. Snellen Test-types.

As originally constructed, Snellen's test-card had seven rows of letters on it, the largest at the top, the smallest at the bottom, each row being marked at the distance at which it should be seen. For instance, the top row should be seen at sixty metres, or two hundred feet, the next row at thirty-six metres, and so on down to the bottom row which should be seen at six metres, or twenty feet.

The smallest letter distinctly read shows the acuteness of vision of the patient: e. g., say the patient can read only the top line, it is expressed as follows—6/60 metres or 20/200 feet—the numerator of the fraction showing the distance at which it is read and the denominator the number of the line, and this expresses the patient's acuteness of vision, showing that he sees at 20 feet what he should see at 200 feet, or that the vision equals but 1/10 what the normal eye should have. If the second line is read it should be marked V = 6/30 or 20/100, and if the seventh or bottom line is read it is marked 6/6 or 20/20, which equals 1, that is normal or unity vision.

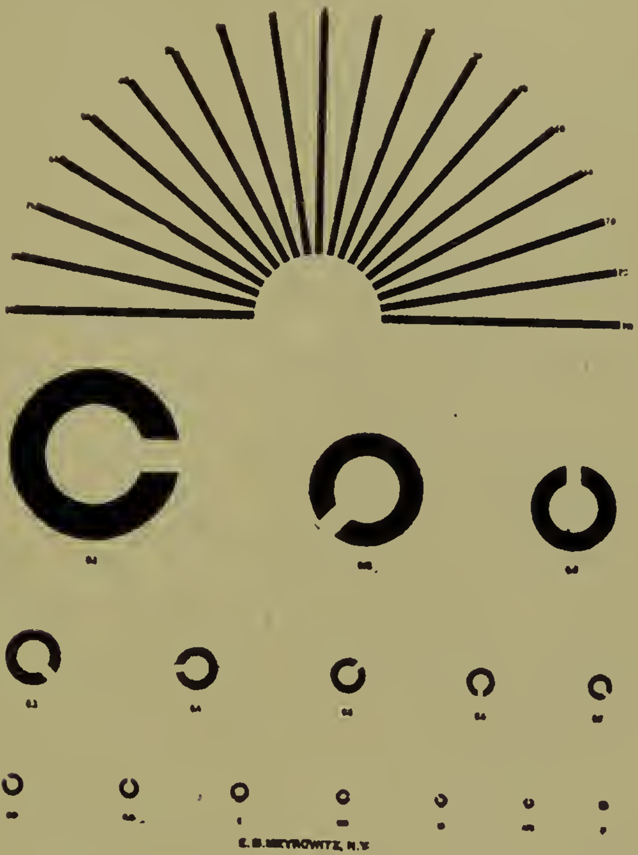


Fig. 24. Landolt's and Jackson's Broken Circles.

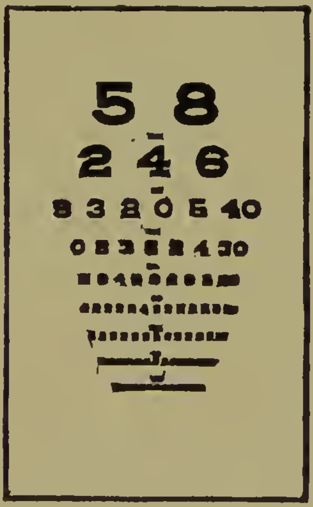


Fig. 25. Figures.

It has been found in practice, however, that many individuals can read smaller letters than those marked on the seventh line of the

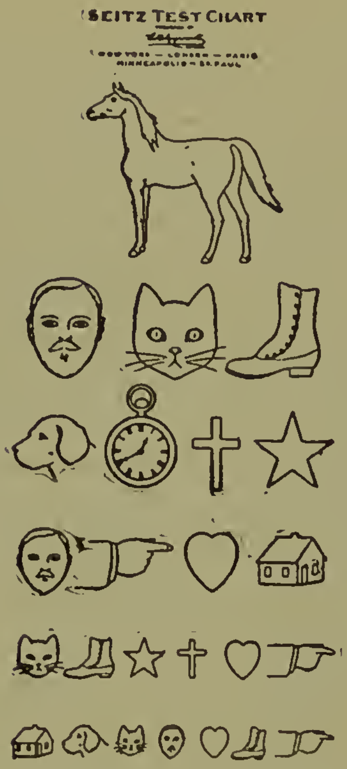


Fig. 26. Familiar Objects.

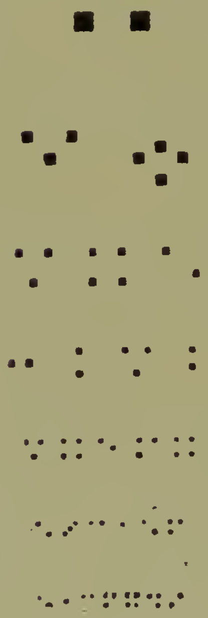


Fig. 27. Fridenberg's Modification of Snellen Test-type.

original Snellen types, consequently two additional lines have been added, 8 and 9, marked respectively 6/4 or 20/15; and 6/3 or 20/10. The vision of a patient who reads the eighth line would be recorded V = 6/4 or 20/15; and the ninth line would be 6/3 or 20/10.

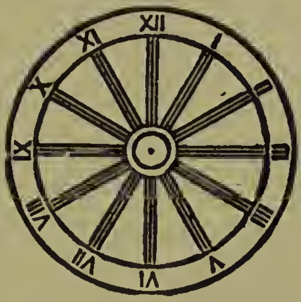
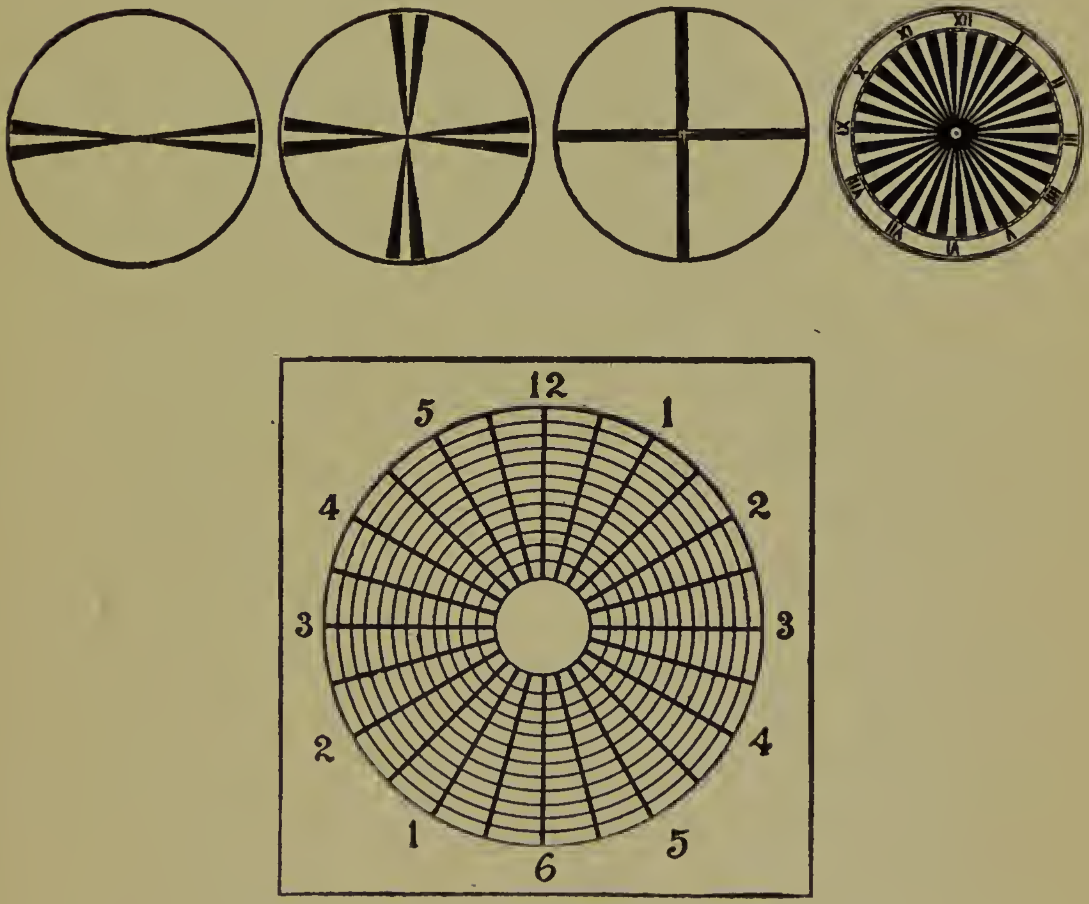


Fig. 28. Green's Clock-dial.



Figures 29, 30, 31, 32 and 33. Verhoeff's Dials.

Instead of adding these two extra lines to the Snellen test-types, which are constructed on a ratio of 5 minutes of visual angle to each letter, other test-types (Wallace) have been constructed on a ratio of 4 minutes of visual angle to subtend each letter at the distance designated on the cards. In this way the letters are relatively smaller than the Snellen letters in each row, and come nearer representing the average normal acuteness of vision.

In case the patient cannot see the largest top letter, the letter is advanced toward the patient, or the patient moved toward the test-types, as is found most convenient. If the patient reads the letter at three metres or ten feet it is recorded V = 3/60 or 10/200, and so on as long as the large top letters can be seen at all. When this letter cannot be seen the fingers are held up at varying distances in front of the patient, and the result recorded.

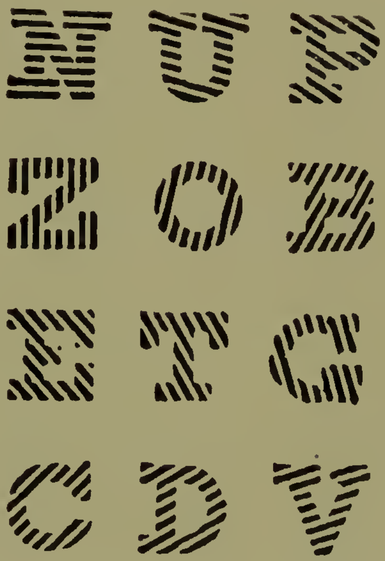


Fig. 34. Pray's Letters.

Should the patient be unable to count fingers, the hand is held in front of him and the distance it is perceived noted. If the patient cannot recognize form (qualitative light) then his ability to perceive light (quantitative light) should be tested by alternately shading and exposing the eye to light, or by intermittingly reflecting or focusing light into the pupil. These results are recorded as follows, V = Pl., V = shadows, or if light is not recognized at all V = O.

CHAPTER VIII.

OBJECTIVE TESTS.

The use of the ophthalmoscope.

To become proficient in the use of the ophthalmoscope requires a great deal of practice, especially is this so with the ordinary ophthalmoscope where the light is from an outside source; and, until the tilting mirror was added to the instrument, it was even more difficult to keep the pupil of the eye under examination illuminated, since the instrument had to be held obliquely to the light, and the sight-hole looked through at an angle. With the introduction of the electric ophthalmoscope the examination of the fundus of the eye became a much easier matter, because here the source of light is from within the instrument itself, and moves synchronously with each motion of the instrument.

The electric ophthalmoscope is particularly valuable in examining patients who are confined to their beds, also infants and patients who from any cause are not very quiet. Beginners in the practice of ophthalmology, and general practitioners who desire to learn the use of the ophthalmoscope will find the electric-lit instrument most practical, and the correct method of using it easily acquired. With the older instrument where the light is from an outside source, each movement of the mirror must be so made that the light is directed on the mirror, and the reflected light from the mirror at the same time directed into the eye of the patient, the co-ordination being necessary to have a proper illumination of the interior of the eye—not an easy task, even for an expert, when the pupil of the eye is small, or the patient restless. Beginners should first practice on a schematic eye, and then on the living subject with the pupils widely dilated.

Two methods of using the ophthalmoscope are available, the *direct* and the *indirect*. [This subject has also been discussed on p. 4748, Vol. VI and under **Ophthalmoscope** and **Ophthalmoscopy in** this *Encyclopedia.*]

The direct method. By this method the eye is examined with the ophthalmoscope without interposing an objective lens between the instrument and the observed eye (see Fig. 35). The image of the illuminated portion of the fundus of the eye is seen in the erect position, and as a virtual image. The rays of light from the ophthalmoscopic mirror (which is usually slightly concave) enter the eye convergently, cross and reach the retina of the eye while diverging. These rays of light are reflected back from the fundus of the observed eye into the eye of the observer. If the examined eye happens to be emmetropic the returning rays emerge parallel; if hypermetropic the returning rays are divergent; if myopic the returning rays are convergent.

If the observer's eye is emmetropic and his accommodation relaxed, he will obtain a clear image of the emmetropic eye examined: he will also obtain a clear image of the hypermetropic eye, either by using his own accommodation sufficiently to bring to a parallel position the divergent rays emanating from the hypermetropic eye, or by rotating a plus lens of sufficient strength back of the sight-hole of the instrument to accomplish the same purpose; if the examined eye is myopic the emmetropic observer must rotate a minus lens of sufficient strength back of the sight-hole to render the emerging convergent rays parallel.

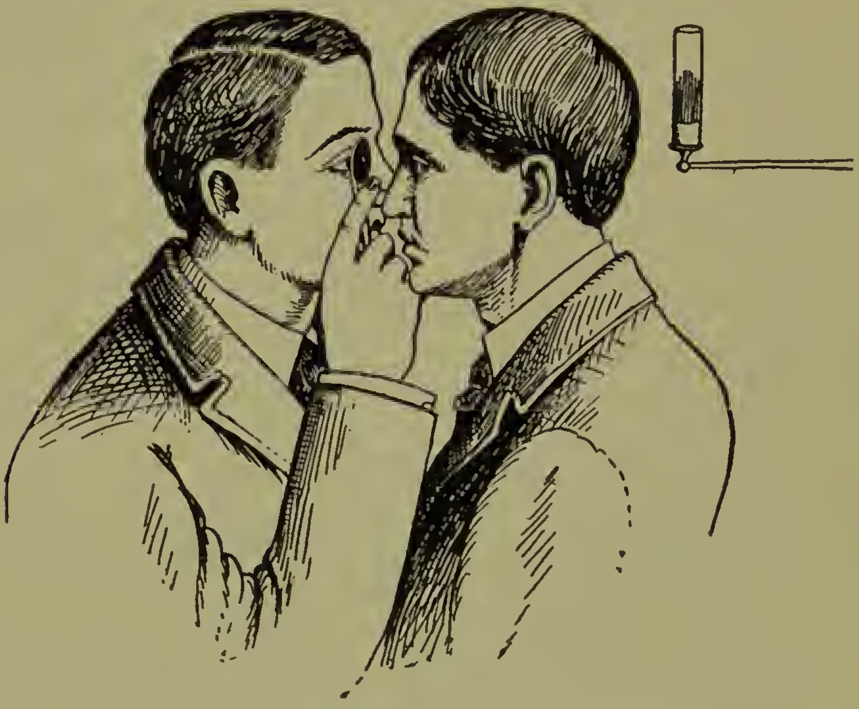


Fig. 35. Ophthalmoscopy. Direct Method.

Should the observer not be emmetropic he should wear correcting glasses when making the examination, or, if he have only a simple hypermetropia or myopia, he may proceed to examine the eye as before, turning on plus or minus lenses until he finds one that enables him to see the fundus clearly. If he himself is hypermetropic and the observed eye is hypermetropic the difference between his own error (which he should know beforehand, and which we will assume to be + 1 D.) and the plus glass it requires to see the fundus of the observed eye plainly (say a + 4 D.) will show the amount of hypermetropia present in the observed eye. In this instance it would be + 4 — (+ 1) equals + 3 D. If it required — 4 D. to see the fundus of the examined eye the patient would really have 5 D. of myopia. That is, a hypermetropic observer must deduct his own hypermetropia from that of a hypermetropic patient and add it to a myopic patient's correction.

The reverse is true if the examiner happens to be myopic. Here the observer must add the strength of his own correction to that of the observed eye if it is hypermetropic and deduct it when the observed eye is myopic.

It is advisable, however, that the surgeon should wear his own correction when examining patients, since in this way errors are avoided, especially with beginners. Or it is possible to have one's correction put in a grooved slot on the back of the ophthalmoscope which can be slid into position back of the sight-hole when a close estimation of refractive errors is made.

In using the direct method the observer should hold the ophthalmoscope (upper extremity) against his brow with the sight-hole in front of his eye and come as near as possible to the eye examined without touching the face of the patient, say to within a half-inch of the front of the eye. The closer the observer can come to the eye under observation the better view is to be obtained, because with the direct method only a small portion of the fundus can be seen at one time.

That portion, however, which is seen is much more magnified than when examined by the indirect method; for instance, images are magnified about 16 or 17 times, the magnification being slightly greater in myopia than in hypermetropia. The optic nerve by actual measurement is about 1.5 mm. in diameter, yet, when viewed with the ophthalmoscope by the direct method, it is, as above stated, magnified 16 or 17 diameters.

The indirect method. Here a positive or plus lens (+ 12 D. to + 18 D.) is held between the examiner and the eye under observation, the lens being held at about its focal length in front of the eye of the patient. The observer at the same time rotates a plus lens (3 D. or 4 D.) back of the sight-hole of the ophthalmoscope. A much wider portion of the fundus is brought into view by this method than by the direct, though not so highly magnified, as in the former (about five diameters in the indirect and about 17 diameters in the direct method). The image seen is a real and an inverted one, and is situated at the focus of the lens held in front of the patient's eye.

The observer moves his own head backward and forward, or moves the objective lens slightly backward and forward, until a clear view of the fundus is obtained. The light should be back of the patient, slightly above and, as a rule, on the side corresponding with the eye under examination (on the right for the right eye, on the left for the left eye) though this is not absolutely essential in the indirect method of examination. The observer also should be on the same side as the eye examined, and at an angle of about 15 to 20 degrees from the meridian plane of the eye, so that when the light is reflected into the eye it strikes near the optic disc; the objective lens is then interposed, and, as pointed out above, by slight maneuvering of the head backward and forward and shifting the interposed lens, the optic nerve or some of the larger blood vessels are brought into view. After obtaining a clear image the patient is directed to look up and down, right and left, to bring all parts of the fundus under observation.

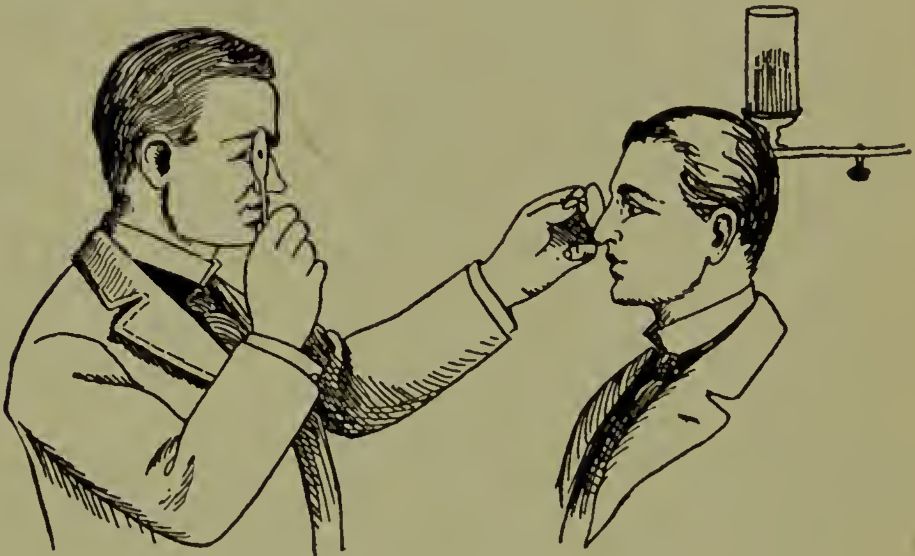


Fig. 36. Ophthalmoscopy. Indirect Method.

This is a better and more satisfactory procedure than for the observer to move his own head.

It should always be remembered that the image in the indirect method of examination is an inverted one. For instance, when looking at the optic nerve, the upper part of the image corresponds to the lower part of the nerve, and the lower part of the image to the upper part of the nerve, the right side of the image to the left side of the nerve, and the left side of the image to the right side of the nerve, etc.

In examining the finer details of the fundus the direct method is superior to the indirect because of the much greater magnification; also in measuring errors of refraction it is a much more accurate method than the indirect, in fact the indirect method has about been given up as a method of measuring refractive errors.

However, in high degrees of myopia or when there is much haziness of the refractive media, the indirect method is to be preferred to the direct. In fact, in very high degrees of myopia, the indirect method is the only satisfactory one of examination, and in these cases it is not necessary to interpose a lens in front of the patient's eye. For example, in a myopia of 20 D. an inverted real image would be formed two inches in front of the eye. The observer with a + 4 D. lens back of the aperture on the ophthalmoscope moves his head backward and forward until he gets a good view of this image. If the examiner wishes to magnify the image further he can, of course, interpose a lens, as is usual in this method of examination.

When using the *direct* method of examination the patient should be seated on a low stool in a darkened room with the light back of him and slightly to the side (to the patient's right or left according as it is the right or the left eye which is being examined), and about on a level with the patient's eye. The light may be a frosted electric bulb, an argand gas burner, an oil lamp, or even a candle if nothing better is to be had.

The surgeon should sit in front and to the side, facing the patient and on a slightly higher stool. The surgeon should examine the patient's right eye with his right eye, and the patient's left eye with his left eye.

The patient should look straight ahead with both eyes open, and the surgeon should keep both of his eyes open when making the examination. By leaving both eyes open both the surgeon and the patient more easily relax the ciliary muscles and avoid spasm of the accommodation. The surgeon should not approach too closely to the eye at first, but start at a distance of from fifteen to twenty inches, and, while looking through the aperture, let the light fall into the eye of the patient at an angle of about 15 degrees to the temporal side of the median plane of the eye so that the region of the optic disc may be illuminated; and before approaching near the eye the patient should be made to look up, down, to the right, and to the left, in order to detect any small opacities on the cornea or in its substance, or on its posterior layers, or any opacities in the crystalline lens, vitreous, etc. Often small opacities in the cornea, crystalline lens and vitreous are overlooked if the observer approaches very close to the examined eye without having glanced at the eye first at a little distance. Any opacities having been noticed, a strong plus glass may be rotated back of the aperture and closer inspection of the opacities made. Oblique illumination often aids in locating the exact position of the opacity if it is in the cornea, lens or anterior portion of the vitreous, or the observer may remain 15 to 20 inches directly in front of the patient and, looking through the aperture of the instrument, have the patient look up and down, right and left, keeping the pupil illuminated all the while, and by noting the parallactic displacement of the opacity with reference to the border of the pupil its location may be determined. An ophthalmoscopic study of the position of intraocular deposits and of the normal parts at the fundus will greatly help to teach the use of the instrument in refraction work.

If an opacity moves in the same direction with the eye-movement and approaches the border of the pupil in that direction it must be situated in the cornea; if the opacity remains in the center of the pupil it must lie in the plane of the pupil, and therefore, be on, or in, the anterior capsule of the lens; if the opacity moves in the opposite direction from the motion of the eye, it lies in the crystalline lens on its posterior capsule, or in the vitreous. The more deeply situated the opacity the more quickly will it approach the pupil border on the opposite side to the movement of the eye itself, and if the eye movement is extensive the opacity disappears back of the iris border.

By having the patient move his eye rapidly first in one direction, then another, floating opacities in the vitreous may be brought into view; or if a detachment of the retina is present, the grayish mass may be seen; or if extensive exudate into the vitreous has taken place, it may be seen while the observer is some distance from the eye (12 to 15 inches), especially with a dilated pupil. Small vitreous opacities when viewed in this way are dark or black in appearance, while the larger ones are grayish, enough light being reflected from them to show their true color. To observe the fine opacities it is necessary to use the plane mirror and a subdued light. The larger opacities are to be studied with the concave mirror and a bright light. As the eye is approached plus lenses must be rotated back of the aperture of the ophthalmoscopic mirror to get a clear and magnified image of the opacities, the intensity of the illumination being changed now and then, as by this contrast in light and shade the opacities are better seen.

Having taken a view of the eye at a distance the observer may approach very close to the eye keeping the pupil illuminated the while. The parts to be observed are: (1) The *optic disc.* (Perhaps it is always better to begin the examination with the indirect method by which a wider and more comprehensive view of the fundus is to be had, then to follow with the direct method and examine different parts of the fundus in detail.) The first appearance of the optic disc or nerve head, is that of a round or oval, whitish to light grayish-pink spot, surrounded by a deeper pink field, the reflex from the choroid. At the center of this disc and usually extending slightly to the temporal side, is a depressed white spot, the physiologic cup. From this cup, nearer the nasal side than the temporal, the retinal blood vessels emerge. In young subjects the physiologic cup may be lacking or very small, while in older persons it may not only occupy a space near the centre of the disc, but may extend quite to the temporal border. As a rule the physiologic cup occupies but a small space near the center of the disc varying in depth from 1 to 3 D., but occasionally it extends (as above stated) to the temporal border and almost to the nasal border, and may have a depth of 3 to 4 D. or even greater.

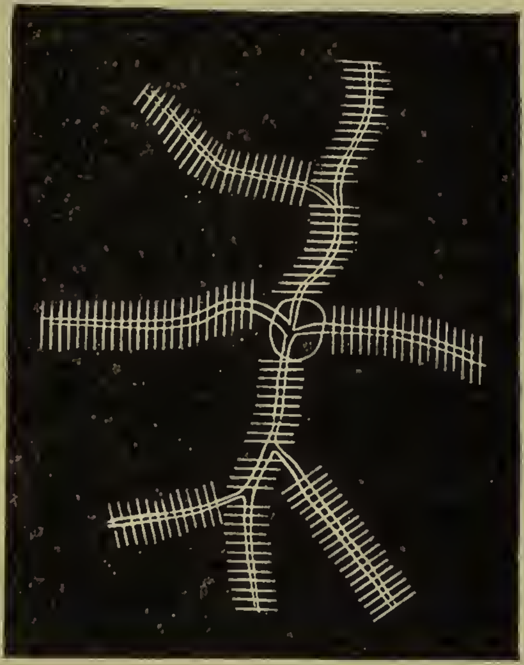


Fig. A. Focusing of the Vessels by the Meridians of an Astigmatic Eye. The parallel lines on each vessel represent the direction of the meridians through which a distinct image of the vessel is obtained. (de Schweinitz.)

The white appearance of the bottom of the disc is due to the light reflected from the lamina cribrosa, and the white, grayish stippling is due to the lacunæ in the laminæ.

Frequently surrounding the optic disc or nerve head are two rings, a white and a pigment. Often they are incomplete and occupy only the temporal side, or they may extend completely around the disc. The white ring may be present and the pigment absent, though the partial or incomplete white ring is the most constant. Especially is this the case in myopic eyes. This white ring surrounding the optic disc is the edge of the sclera which is left exposed to view by the choroid not coming flush up to the optic nerve, as does the sclera. The outer pigment ring which is often incomplete, irregular, or wanting altogether, is choroidal pigment collected at this position. The retinal vessels emerge from the center of the optic disc, nearer the nasal side than the temporal. Usually there are two main arteries and two main veins each of which divides into two main branches, either on the disc or shortly after leaving it; thus two large arterial branches extend upward and two downward, and in like manner the veins.

(2). *The retinal vessels.* From the nasal side of the disc, and also from the larger vessels near the disc, a few small and medium sized vessels are given off, which extend into the nasal half of the retina, and from the larger vessels, both above and below, and on each side of the fundus, smaller vessels are given off which approach each other on the temporal side towards the macula, but not extending over it.

The above ophthalmoscopic appearances of the disc and retinal blood-vessels are given in detail, since they are the landmarks by which we estimate the refraction of the eye. The edges of the disc and the medium-sized vessels are selected for observation when making the measurements. As indicated above, simple hypermetropia and myopia are not difficult to measure, and in most cases can be estimated to within 50 D. to 1 D. of the total error if made with the proper surroundings. The estimation of astigmatism with the ophthalmoscope is more difficult, and requires much experience and practice to arrive at anything like accurate results. The direct method is the one generally employed.

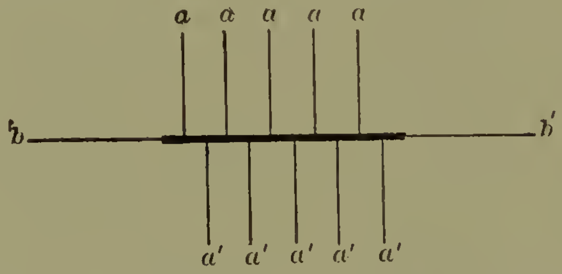


Fig. 37. Showing how Lines are Seen by Rays of Light that Strike them from Side to Side, *a*, *a'*, and not by Rays that Strike them at their Ends, *b*, *b'*.

As the edges of the disc and the retinal blood vessels are the objective points observed in making these measurements it is well to state just how they are brought into view. The edges of the disc and the retinal vessels may be considered as lines; and a line is seen by means of the rays of light that strike it from side to side and not from its longitudinal direction; a glance at figures 37 and 38 shows this clearly.

Vertical lines and what amounts to the same thing in the eye, the lateral sides of the optic disc and the vertical retinal vessels, are seen by rays of light that strike them from side to side; and this means that, in the eye, the vertical vessels, and the lateral margins of the disc, are seen by the rays passing through the horizontal meridian of the cornea, and, *vice versa,* that the horizontal vessels and the upper and lower edges of the disc are seen by the rays of light which pass through the vertical meridian of the cornea.

In large amounts of astigmatism (except in those cases of mixed astigmatism where the hypermetropic and myopic errors are about equal in amount) the whole disc is drawn out into an oval, the long axis of the oval being coincident with the meridian of greatest refraction.

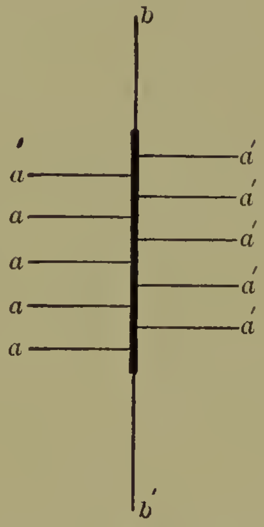


Fig. 38. Showing how Vertical Lines are Seen by Rays of Light, *a*, *a′*, that Strike them from Side to Side.

It is well to bear this in mind, because the strongest plus glass in the ophthalmoscope with which the vertical retinal vessels can be seen distinctly is a measure of the hypermetropia in the horizontal meridian, and the strongest + glass with which the horizontal vessels can be seen measures the hypermetropia in the vertical meridian. If these two measurements are the same it is a case of simple hypermetropia, but if unequal, it shows astigmatism to be present, and the difference between the reading in the vertical and horizontal meridians, is the degree of the astigmatism.

Likewise in myopic refraction, the difference in the strength of the weakest minus glass with which the vertical and horizontal retinal vessels can be seen plainly represents the amount of astigmatism present. Some examples will make the matter plain.

(1) Simple hypermetropic astigmatism with the rule of 2 D. Here

the lateral edges of the disc and the vertical blood vessels should be seen with + 2 D. lens back of the sight hole in the ophthalmoscope, which would indicate hypermetropia of 2 D. in the horizontal meridian of the eye; while the upper and lower edges of the disc, and the horizontal vessels, should be seen plainly with the aperture, indicating emmetropia in the vertical meridian. And the difference between 2 D. and 0 = 2 D., which is the degree of astigmatism present.

(2) Compound hypermetropic astigmatism with the rule, H = 2 D. at 90 degrees, and 4 D. at 180 degrees. Here the lateral edges of the disc and the vertical vessels should be seen with a + 4 D. lens back of the aperture, and the upper and lower edges of the disc and the horizontal vessels with a + 2 D. lens. The difference between 4 D. and 2 D. = 2 D., the amount of the astigmatism.

(3) Simple myopic astigmatism with the rule 2 D. axis 180 degrees. Here the lateral edges of the disc and the vertical retinal vessels should be seen through the aperture, while it requires a — 2 D. lens to see plainly the upper and lower edges of the disc and the horizontal retinal vessels.

(4) Compound myopic astigmatism with the rule, myopia 4 D. at 90 degrees and 2 D. at 180 degrees. Here the lateral edges of the disc and vertical vessels should be seen with — 2 D. lens back of the aperture, and the upper and lower edges of the disc and the horizontal vessels should be seen with — 4 D. lens. The difference between 4 D. and 2 D. = 2 D., the amount of the astigmatism.

(5) Mixed astigmatism with the rule 2 D., myopia 1 D. at 90 degrees and hypermetropia 1 D. at 180 degrees. Here the lateral edges of the disc and the vertical vessels should be seen with a + 1 D. lens back of the aperture, while the upper and lower edges of the disc and the horizontal retinal vessels with a — 1 D., the total amount of the astigmatism being 2 D.

In the above examples it is assumed that accommodation in both the examined and the examiner's eye is relaxed. Furthermore, be it remembered that the strongest plus, and the weakest minus, lens with which the landmarks of the disc and the retinal vessels are seen in the measure of the error of refraction, and the meridian at right angles to the vessels under observation is the meridian measured.

When the axes of the astigmatism run in oblique directions, that is, some distance from 90 degrees and 180 degrees, it is somewhat more difficult to estimate the degree and the axis of the astigmatism. However, in most instances, retinal vessels may be found which lie parallel or nearly so with the chief meridians of curvature, and from these the estimation can be made.

In the medium and higher degrees of astigmatism the surface of the disc itself is drawn out into an oval form, the longer axis of the oval lying in the axis of strongest refraction.

A point of much practical importance in estimating errors of refraction with the ophthalmoscope is to have the patient look in the distance, *and two or three feet higher than the level of his head.* In looking in the distance and *upward* the visual lines have the greatest tendency to swing outward rendering the convergence *nil,* and incidentally the accommodation is relaxed. The same is true, as regards the accommodation, in making the subjective tests with the test-cards. If the test-card is hung somewhat *higher* than the level of the patient's head, the tendency to a relaxation of the accommodation is much enhanced. But even where the patient will not relax the accommodation for the test-types, when taken into the dark room, with nothing in particular to look at, the accommodation relaxes and the error of refraction may be closely approximated by the use of the ophthalmoscope and the retinoscope. In adults, with few exceptions, this may be done. In children it is desirable that a cycloplegic be used.

Retinoscopy or skiascopy.

See **Examination of the eye,** p. 4718, *et seq.,* Vol. VI of this *Encyclopedia;* as well as under **Retinoscopy** and **Skiascopy.** A fuller account of the matter is, however, to be found under **Physiological optics,** p. 9916, Vol. XIII.

The use of the ophthalmometer.

The ophthalmometer, like the ophthalmoscope, is the invention of Von Helmholtz (*Archiv für Ophthal.,* 1854). It is designed to measure the radius of curvature of the cornea in its various meridians. [For a further study of this subject see p. 4709, Vol. VI, and under **Ophthalmometer,** p. 8926, Vol. XII of this *Encyclopedia.*]

It was not until the year 1880, when Javal and Schiötz made improvements in the instrument, that it became practical for every day office work. In 1889 the instrument was still further improved and perfected to facilitate its rapid and accurate use. Although many alterations and different models of the instrument have been made since 1889, none have surpassed the early model in accuracy. The same optical system used in the 1889 model is still employed in the present model of the Javal-Schiötz instruments; the main improvements being in the adjustment and illumination of the mires; together with improvements for quick adjustment and recording the results of the examination. The Universal model is depicted in the text (see Fig. 41) and can be recommended. In this model the large Placido disc of the older instrument has been removed, and a blackened concave solid disc substituted; the mires are transluminous and both are moved by a single wheel rachet which adds to the accuracy of the instrument.

Another instrument that should again be mentioned is the ophthalmophakometer of Souter. This instrument is designed to measure the corneal astigmatism as well as the lenticular astigmatism. It is a modification of, and (in the opinion of the writer) an improvement upon, the Javal-Schiötz ophthalmometer. See p. 4718, Vol. VI of this *Encyclopedia.*

It requires some patience and a little skill to learn the use of the instrument, but once mastered it is of practical value, as it adds another objective test for the measurement of astigmatism.

Other models of the ophthalmometer are those of Chambers-Inskeep, Hardy, Kagenaar, Sutcliffe, Reid, etc., for a description of which see **Ophthalmometer.** The author has used several of these instruments but prefers the Javal-Schiötz model.

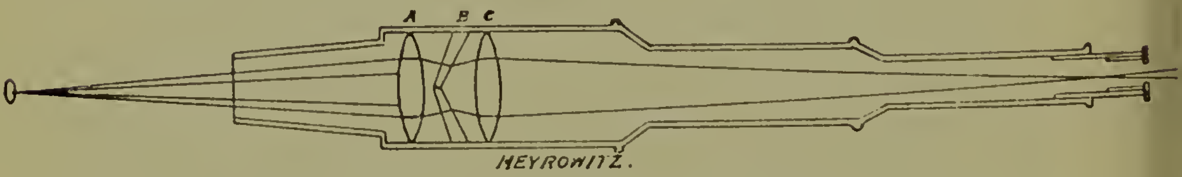


Fig. 39. Birefractive Prism as Placed in the Telescope of the Javal-Schiötz Instrument.

In selecting an ophthalmometer, the *optical system* in the instrument is the most important point to consider. There are two systems employed—first, that in which a bi-refringent prism is used to effect the doubling of the images; and, second, that in which simple glass prisms are used for the same purpose.

The Javal-Schiötz type of instrument employs the Wollaston bi-refringent quartz prism; while the Kagenaar type uses the simple glass prisms. See the figure.

The essential and fundamental difference between the two systems lies in the fact that in the Javal-Schiötz system the doubling of the images is due to the inherent refracting quality of the prism itself (polarization), and is not dependent upon the angle of the prism or its position, while in the Kagenaar and other optical systems the doubling is effected by looking through prisms set at a certain angle.

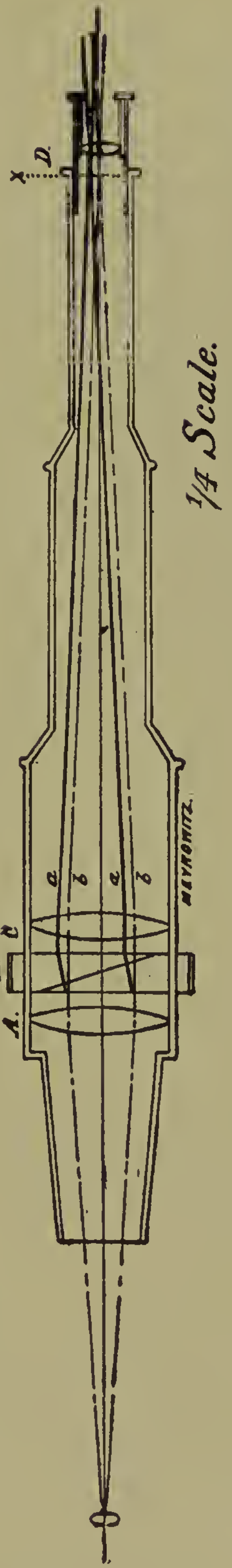


Fig. 40. Glass Slab Prisms in the Kagenaar Instrument.

The Javal system is much superior to that of the Kagenaar, because with slight movements of the eye the images are not altered, whereas with the Kagenaar instrument a slight movement of the eye to the right or to the left causes one of the images to disappear, and ever so slight a movement of the head changes the reading of the instrument. The same objection holds against the Sutcliffe instrument, the slightest movement of the eye causing a change in the reading.

Rules for the use of the ophthalmometer.

A brief description and picture of the instrument with some of the rules for its use are given on p. 4714, Vol. V and on p. 8928, Vol. XII of this *Encyclopedia*. It is desirable, however, to call attention to two or three features of the latest form of the instrument.

The optical system of the Universal model is a Wollaston birefringent quartz prism mounted between two achromatic objectives of 27 cm. focus each. (See Fig. 39.)

The advantage of this system over that in which ordinary glass prisms or slabs are used, as stated above, are: First, the images are very clear, showing slight amounts of over-lapping, even as low as .25 D. Second, slight movements of the eye do not disturb the relationship of the images of the mires, as is the case with instruments in which glass prisms are used. Third, the *mires* are the familiar steps and parallelogram devised by Javal and Schiötz for the 1889 model. In the author's opinion this is the best set of mires yet devised, as the clear-cut *black* lines dividing the center of these *white* plates, and running at right angles to the tangent position of these plates, make it very easy to tell when they are directly opposite and coincident, thus designating clearly when the chief meridians of curvature of the cornea are reached. This is a most important factor, for upon the result depends the axis at which the cylindrical glass, which corrects the astigmatism, shall be worn. This is true with very few exceptions, as generally the axis for the total astigmatism of the eye corresponds with that of the corneal astigmatism.

In this model of the ophthalmometer the mires are transluminous, therefore it is better to have the instrument in a darkened room as the images of the mires are much clearer and more sharply defined that when seen in a light room.

(1) Place the patient so that his chin rests comfortably in the chin rest at the same time that his brow presses firmly against the horizontal part of the head rest.

(2) Locate and focus the eye. The level of the eye can be roughly located by looking through the sight-holes in the disc lateral to the telescope. Then by moving the instrument to the right or to the left, as the case may require, the images of the mires reflected from the cornea will come into view. If the images are slightly too high or too low the instrument can be raised or lowered by means of the adjustment at the side of the upright column. In order to get the images into exact focus move the telescope forward or backward by turning the milled wheel at the side of the telescope. When the images are in perfect focus, we are ready for the next step.

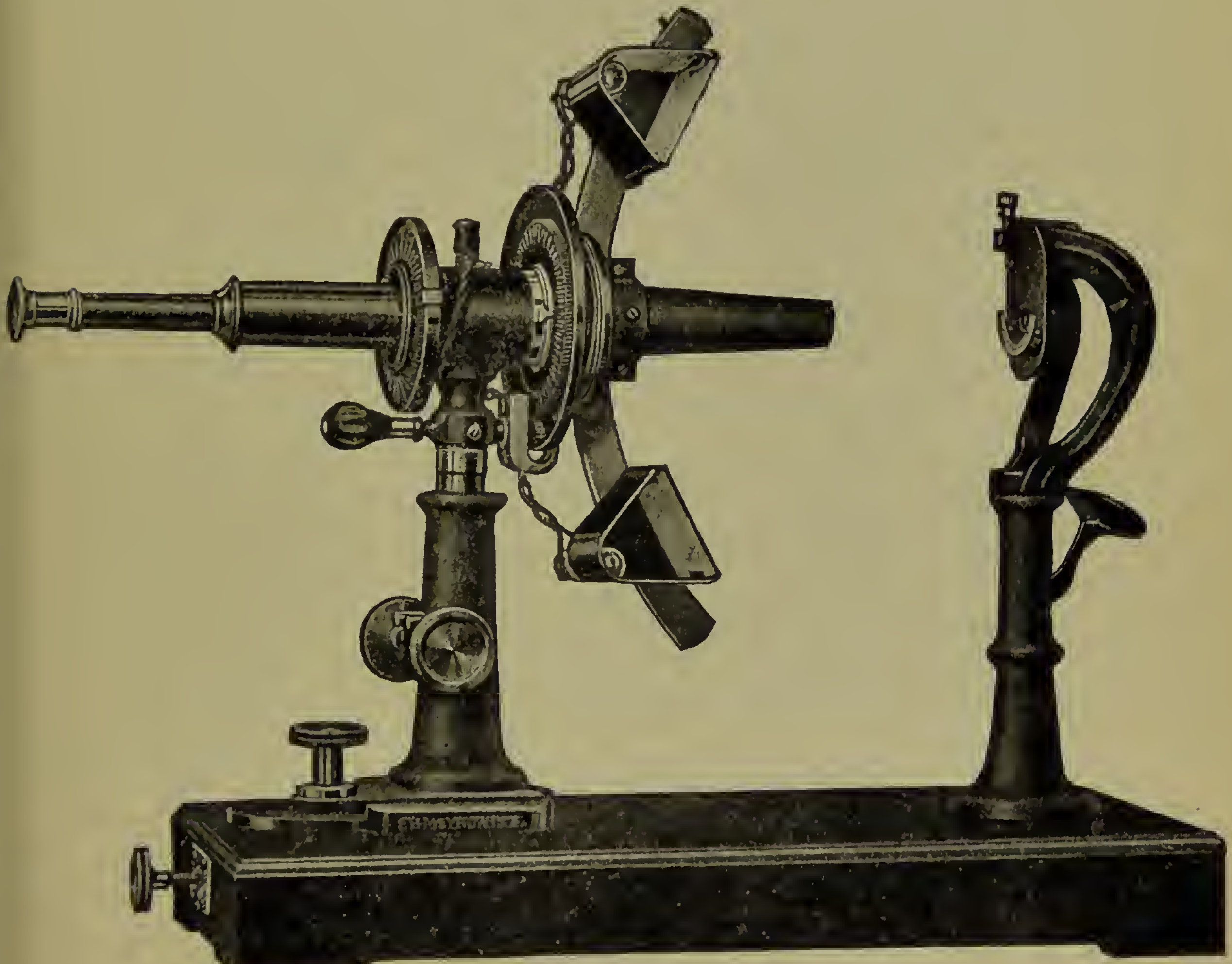


Fig. 41. Universal Ophthalmometer. (E. B. Meyrowitz.)

(3) *Primary position.* The "primary position" is that point at which the transverse lines dividing the mires become coincident and form one continuous straight line; which indicates (when there is any astigmatism) that one of the chief meridians of curvature of the cornea has been reached. The other meridian, in the great majority of

cases, is 90 degrees from this, therefore at right angles to it, and is the "secondary position." When there is no astigmatism the transverse black lines are opposite and coincident in all positions.

In the Universal model there are two pointers operating on the dioptric scale, each has two oval openings so that the scale can be read, and one has an extension hook. The pointer without the hook rotates with the rotation of the telescope, but the one with the hook is stationary, except when moved by hand. Now to obtain the primary position rotate the *telescope* until the pointer *without the hook* stands exactly at 0. If the transverse lines are straight with each other at this point, go no farther, as this is the primary position. Approximate the mires until their edges just touch, by rotating the *disc* on the telescope. We are then ready for the next step.

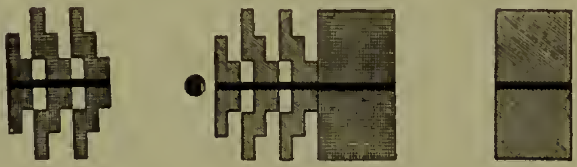


Fig. 42. Primary Position of the Mires.

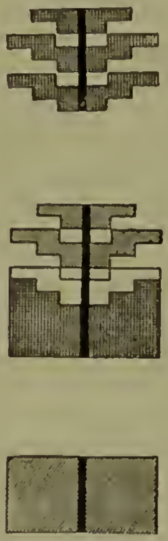


Fig. 43. Secondary Position of the Mires.

(4) *Secondary position.* To obtain this rotate the telescope 90 degrees. If the mires overlap there is "astigmatism with the rule," and the number of steps of overlapping represents the amount of astigmatism. Say it overlaps three steps; it should be recorded thus—astigmatism with the rule, 3 D. 90° + 180° —. Fig. 42 shows the pri-

mary position of the mires as reflected from the cornea. Fig. 43 shows the secondary position in like manner.

If the mires separate when the second position is reached, it indicates astigmatism against the rule. The edges of the mires should be approximated again and the telescope rotated back to the primary position when the mires will overlap, say three steps, written thus: astigmatism against the rule, 3 D. 180° + 90° —. [Or it may be written 3 D. + 180°, or 3 D. + 90°.—*Ed.*]

If the transverse black lines do not become coincident at 0°, rotate the telescope until these lines become coincident, but not farther than

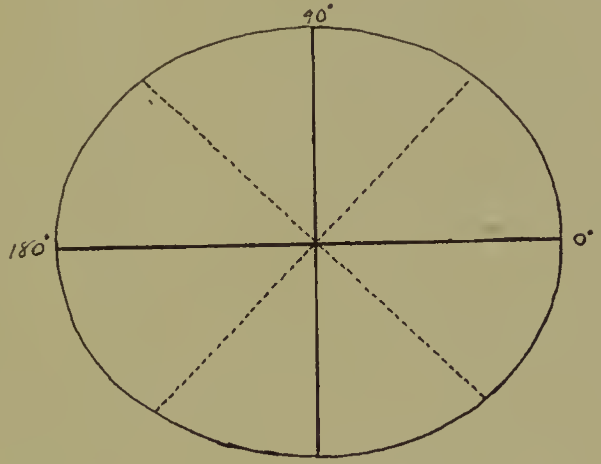


Fig. 44. Showing how the Mires Must Line in an Arc of 90°.

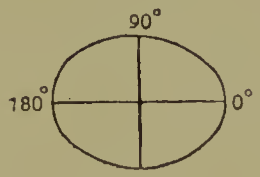


Fig. 45. Showing Front View of an Eye with Astigmatism With the Rule.

45° to either side of the 0°, as the primary position is never farther removed than 45° to either side of 0°, and the lines must necessarily become coincident within an arc of 90° on the circle (see Fig. 44).

It will be noticed that the axis scale has the 0° at the top and bottom in the vertical meridian. This is so placed because the movable pointer is at *right angles* to the arc of the instrument whose position it indicates. This point is repeatedly emphasized, because, if we rotate the telescope so that the movable pointer goes beyond the 135° mark on the one side, or the 45° mark on the other, we make the instrument read "astigmatism against the rule," when it is really "with the rule," and vice versa. When the lines become coincident at 135° or 45°, the extreme limits, being just half way between 0° and 90° on either side, by preference take 135° as the primary position—this for the sake of nomenclature. We see then that the primary position may be at 0° or within 45° of that point, but never beyond.

Why the mires overlap in astigmatism with the rule; why they separate in astigmatism against the rule. It is well-known that, in astigmatism with the rule, the images of the mires overlap when turned from the primary to the secondary position; and that these same images, in astigmatism against the rule, separate when turned from the "primary" to the "secondary" position.* Why is this so?

Fig. 45 shows the general form of the cornea, front view, in astigmatism with the rule.

We will assume a case with the two chief meridians of curvature at 90° and 180°, exactly. In such a case the "primary" position would be found at 180°. If the inner edges of the images are then approximated and the arc turned 90° to the "secondary" position, the doubled images of the object under measurement cannot become smaller from side to side (the deviation caused by the prism remaining the same) except by overlapping at their inner edges, which they do. And the greater the difference in curvature of the two chief meridians the more overlapping there will be in astigmatism with the rule.

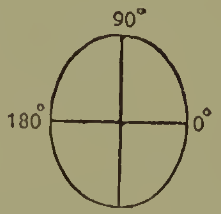


Fig. 46. Diagram of Front View of an Eye with Astigmatism Against the Rule Showing a Vertical Oval.

In astigmatism against the rule, just the reverse holds, that is, the images separate when turned from the primary to the secondary position. A glance at Fig. 46, which represents the general form of the cornea, front view, in astigmatism against the rule, easily explains this. Here the doubled images of the mires are approximated on a meridian with a shorter radius of curvature than the vertical meridian. Consequently, when the mires are turned to the secondary position, 90° in this instance, to a meridian with a longer radius of curvature, the images must become larger. But since the deviation caused by the prism is a constant one (2.95 mm.), the doubled images cannot become larger from side to side, except by pulling apart or separating at their inner edges, which they do. The greater the difference in the radius of curvature of the two chief meridians the greater the separation of the images.

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* In passing, it may be said that the "primary" position is nothing more than the starting point, or the *first* position in which the lines dividing the mires into halves become straight with each other, showing that one of the two chief meridians of curvature of the cornea has been found. Hence it is called "primary" or first position. The "secondary" position is at right angles to the "primary" and is called "secondary" simply because it is the second position reached.

With the above explanation, it is easy to see why the images *always overlap* when the astigmatism is with the rule and *always separate* when it is against the rule. Consequently, when we have an eye under observation with the ophthalmometer, we know immediately, if on turning the arc from the primary position to the secondary and an overlapping of the images occurs, that we have astigmatism with the rule. If, however, the images separate when the arc is turned from the primary to the secondary position, we know at once that the astigmatism is against the rule.

The instrument, therefore, *indicates* something and *means* something when the images either overlap or separate. If the images neither overlap nor separate on turning the arc from the primary to the secondary position, it shows that there is no corneal astigmatism at all. In such cases the patient sometimes takes a weak cylindrical glass (about .50 D.) against the rule, that is, — .50 D. cylindrical, axis 90° or near it, if the patient is myopic, or + .50 D. cylindrical, axis 180° or near it if hypermetropia is present. This is explained by the presence of a small amount of lenticular astigmatism which is nearly always present, and against the rule. (Or it may be accounted for by an astigmatism of the posterior surface of the cornea, which sometimes amounts to as much as 1 D.) Consequently we should be on the lookout for this in such cases. Many times, however, when the ophthalmometer shows no corneal astigmatism the patient accepts no cylindrical glass at all.

(1) In astigmatism with the rule we usually have to deduct half a diopter from the reading of the instrument, that is, the patient will not accept as much as the instrument gives by .50 D. This can be explained best by an illustrative case. Say the instrument reads astigmatism *with the rule* 2.50 D., axis 90° or 180° —. We will assume also, for the sake of simplicity, that it is a case of simple hypermetropic astigmatism. Fig. 47 shows a vertical and horizontal sec-

tion of such an eye, and where the rays of light focus. A front view of the cornea and lens is also given in order to show the outlines of their front surfaces. It is evident that, in order to have the rays of light in the vertical meridian focus on the retina, both the cornea and the lens must be emmetropic in the vertical meridian; or at least their combined refractive power must be emmetropic in effect.

But the horizontal meridian of the cornea is flatter by 2.50 D. than the vertical meridian, as measured by the instrument; and if the patient had no lenticular astigmatism, it would require a + 2.50 D. cylindrical glass to correct this and bring the rays to a focus on the retina. But, as a matter of fact, in such a case the patient usually will accept but 2 D. cylindrical glass. This can be explained best, it seems, by assuming a lenticular astigmatism, myopic in nature, of .50 D. in the horizontal meridian. This would neutralize that amount (.50 D.) of the hypermetropic corneal astigmatism in the same meridian, leaving but 2 D. of total astigmatism to be corrected by a glass.

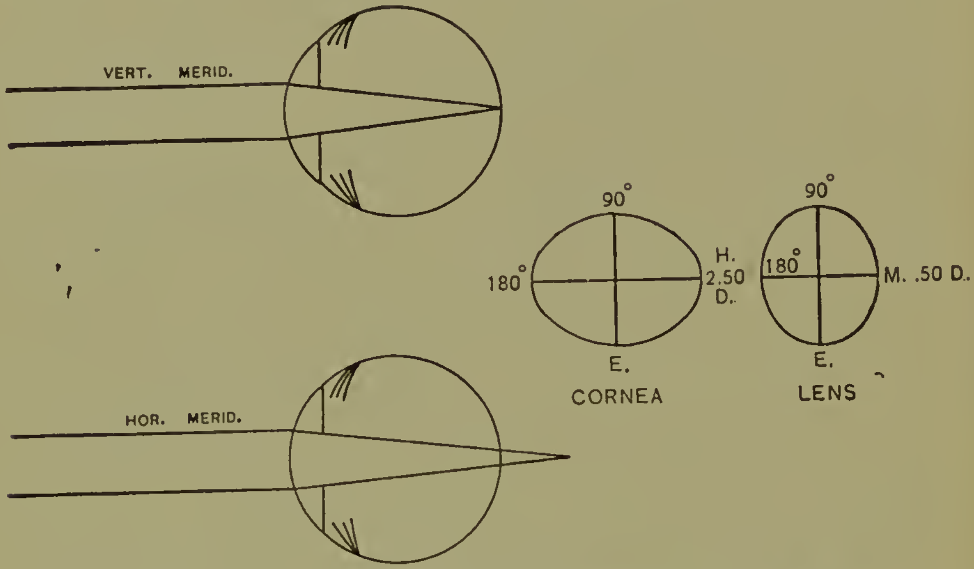

Fig. 47. Vertical and Horizontal Sections of the Right Eye.
The cut also shows cornea and lens; simple hypermetropic astigmatism with the rule.

What is true in hypermetropic is also true in myopic cases; see Fig. 48.

Here the diagram shows a case of simple myopic astigmatism with the rule 2.50 D. axis 90° + and 180° —. In order to have the rays of light in the horizontal meridian focus on the retina, both the cornea and the lens must be emmetropic in the horizontal meridian (that is, their combined refractive power). But the vertical meridian of the cornea is more curved than the horizontal by 2.50 D. as shown by the ophthalmometer, therefore it requires a —2.50 D. cylindrical glass, axis 180°, to correct it, if no lenticular astigmatism is present. As a rule the patient will accept but a —2 D. cylindrical glass. This is to be accounted for by the lens being hypermetropic-astigmatic .50 D. in the vertical meridian, thereby neutralizing that amount of the corneal astigmatism, and but 2 D. of total astigmatism is left to be corrected.

The lenticular astigmatism is not always exactly .50 D., but may be more or less. Sometimes it is only .25 D., or may be absent. Again, it may amount to .75 D., or 1 D., and exceptionally to even larger amounts. As a rule, however, it measures .50 D. or .75 D., and in astigmatism with the rule, being of an opposite kind and in the same meridian with the corneal astigmatism, it neutralizes to that extent the corneal astigmatism.

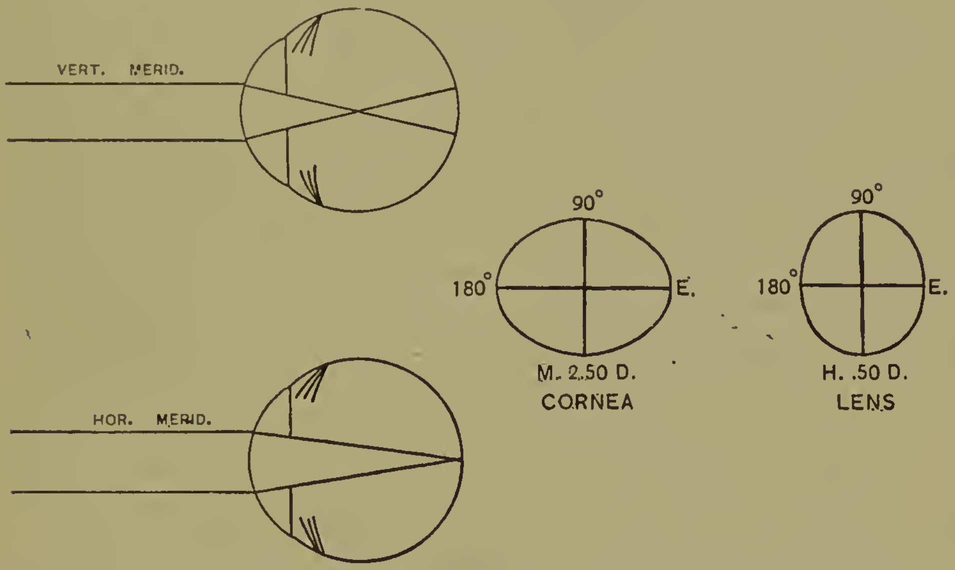

Fig. 48. Vertical and Horizontal Sections of the Right Eye; also Front View of the Cornea and the Lens; simple myopic astigmatism with the rule.

(2) In astigmatism against the rule we usually have to add a half diopter to the reading of the instrument, that is, the patient accepts that much more.

Illustrative cases will serve to elucidate the case. Say the ophthalmometer reads, astigmatism 2.50 D. against the rule, axis 180° + 90° —. To simplify matters we will assume it to be a case of simple hypermetropic astigmatism.

It is plain from Fig. 49 that both the cornea and lens are emmetropic in the horizontal meridian because the rays of light passing through this meridian focus on the retina. But the instrument shows the vertical meridian of the cornea to be flatter by 2.50 D. than the horizontal meridian; and if no lenticular astigmatism was present it would take a + 2.50 D. cylindrical glass, axis 180°, to correct same. As a matter of fact, the patient usually accepts a half diopter more than the instrument says. This can be accounted for by a half diopter (.50 D.) of lenticular astigmatism in the vertical meridian, hypermetropic in nature, and, therefore, of the *same* kind as the corneal astigmatism. In other words, both the cornea and lens are hypermetropic in the vertical meridian, the cornea 2.50 D. and the lens .50 D., the two added together making 3 D. the total astigmatism consequently requiring a + 3 D. cyl. axis 180° to correct same. The same law holds good in myopic cases.

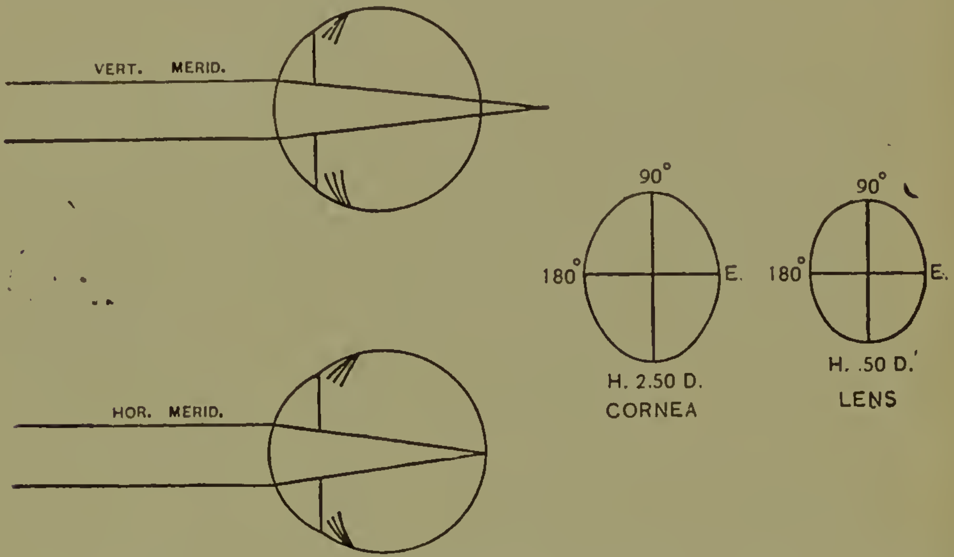

Fig. 49. Vertical and Horizontal Sections of an Eye with simple Hypermetropic Astigmatism Against the Rule; also Front View of the Cornea and the Lens in Outline.

Many times, however, in astigmatism against the rule, the patient accepts exactly the glass indicated by the ophthalmometer, showing that lenticular astigmatism is often entirely absent in such cases.

The whole explanation given above on this question may be summed up in two short sentences. (1) In *astigmatism with the rule* the lenticular astigmatism is in the *same* meridian as the corneal astigmatism, but is of an *opposite* kind, and usually mounts to half a diopter, thereby neutralizing that amount of the corneal astigmatism. (2) In *astigmatism against the rule* the lenticular astigmatism is in the *same* meridian as the corneal astigmatism, is of the *same* kind, and usually amounts to half a diopter, therefore adds that amount to the corneal astigmatism. (However it should not be forgotten that the unequal curvature of the *posterior* surface of the cornea can and may modify the astigmatism of the *front* surface of the cornea.)

Since the introduction of the Souter ophthalmophakometer we do not have to depend on the subjective tests for the determination of the lenticular astigmatism. By means of this instrument we can measure *objectively* the lenticular astigmatism, and in this way confirm the subjective tests, as well as the objective tests with the ophthalmoscope and retinoscope.

The reading of the ophthalmometer when the two chief meridians of curvature of the cornea happen to be at 45° and 135°, or exactly halfway between 0° and 90° on one side, and 90° and 180° on the other side should receive a little further consideration here, in order to make the matter entirely clear.

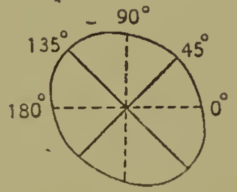

Fig. 50. Front View of an Eye showing the two chief Meridians of Curvature at 45° and 135°.

There are certain exceptional cases where the two chief meridians of curvature of the cornea are just halfway between 0° and 90° and 180°, that is, exactly at 45° and 135° (see Fig. 50).

Now 45° is no nearer to 90° than it is to 0°, consequently it is not in the neighborhood of one or the other. So with 135° as regards 90° and 180°, it is just as near one as the other, and is not in the neighborhood of either.

What are we to do in such a case as regards "astigmatism with the rule" and "astigmatism against the rule"? Strictly speaking, in such cases, there is no such thing as "astigmatism with the rule" and "astigmatism against the rule," simply because the two chief meridians of curvature are exactly on the halfway mark or dividing lines of what it takes to make astigmatism with, or against, the rule. But how does the ophthalmometer work in such cases? In them we search for the primary position as usual by beginning with the pointer with the extension hook at 0°. We know when we are in the primary position by the two narrow black lines which divide the mires into halves becoming straight with and opposite each other, which they do when either of the chief meridians of curvature of the cornea is reached. In the present case these lines would not be straight when we turn the pointer with the extension hook to 0°, because neither of the chief meridians is there. Following the direction given above, we turn the pointer with the extension hook from 0° toward 135°; when 135° is reached (one of the chief meridians of curvature in this instance) the narrow black lines dividing the mires become straight with each other. This is the primary position. We then approximate the images and turn the arc at right angles to the primary position (pointer with the extension hook to 45°) to obtain the secondary position. If the meridian at 45° proves to be more curved than the one at 135° the images will overlap.

According to the language of the instrument, that is, when overlapping occurs, this would be a case of astigmatism with the rule. Though, as a matter of fact, we know, and have just explained above, that there is really no such thing as astigmatism with or against the rule, when the chief meridians of curvature are at 45° and 135°. However, for the sake of uniformity of expression and to make the readings of the instrument, *overlapping* and *separating* of the images, mean a definite something in *every case,* it is well to apply the terms ''astigmatism with the rule'' and ''astigmatism against the rule,'' even to the meridians at 45° and 135°.

It is altogether important also in such cases to take either 135° or 45°—one or the other—always as the primary position, and not first one and then the other as the primary position. A glance at Fig. 50 will show why this is necessary. If we start at 135° as the primary position, the meridian of longest radius of curvature, and then turn to 45°, the secondary position, to the meridian of shortest radius of curvature, the images will overlap, showing *astigmatism with the rule.* However, should we take 45° as the primary position, the meridian of shorest radius of curvature, and then turn to 135°, at right angles, a meridian with the longer radius of curvature, the images would separate, showing thereby *astigmatism against the rule.* In other words, the instrument would read with the rule and against the rule, *in the same eye,* accordingly as we assumed 135° or 45° as the primary position. As we cannot very well have astigmatism both with and against the rule in the same eye, it is best, in such cases as the above, to assume one or the other of these meridians *always* as the primary position. Individually, and in the rules which have been formulated for the use of the instrument, we always assume 135° as the primary position in such cases. The meridian at 45° could be taken just as well, provided it was always taken as the starting or primary position. [Many authorities regard as myopic astigmatism with the meridian of greatest curvature at 180° or a hypermetropic astigmatism with the meridian of greatest curvature at 90°, as the only examples of astigmatism "with the rule." All other *relations of the meridians are regarded as "against the rule*." This classification has at least the merit of simplicity.—*Ed.*]

Scheiner's test in refraction. This consists in holding before the eye under examination, a card-board with a double perforation, the holes being near enough together so that rays passing through each enter the pupil at the same time. Have the patient look at a candle 20 feet distant. If the eye is *emmetropic* the rays passing though the two perforations will meet exactly at the retina (assuming that accommodation is relaxed) and the patient will see but one image of the object.

If the eye is *myopic* the rays will meet before reaching the retina, cross and diverge, forming two images of the object on the retina.

This diplopia (assuming that the perforations are held in the horizontal plane) is homonymous, and the farther apart the images, the higher the myopia. The strength of the minus glass, placed back of the perforations, which fuses the images is the measure of the myopia.

If the eye is *hypermetropic* the rays of light passing through the perforations will not meet before reaching the retina, but form two images on the retina. This diplopia is a crossed one, and the wider apart the images the greater the hypermetropia. The strength of the plus glass placed back of the perforations which brings the images together is the measure of the hypermetropia.

A red glass is used in order to determine if the diplopia is homonymous or crossed, which reveals the nature of the error of refraction, if myopic or hypermetropic.

This method of testing the refraction has long since been given up as a practical office test.

PART II. CLINICAL APPLICATIONS OF REFRACTION METHODS.

CHAPTER IX.

Simple hypermetropic astigmatism; Simple hypermetropia; Illustrative cases.

The following rules in refraction work are followed by the writer: 1. Use the ophthalmometer. 2. Use the phakometer. 3. Use trial lenses and test cards. 4. Use the ophthalmoscope. 5. Test the extrinsic muscles. 6. If after two tests on different days the result is still unsatisfactory, employ a cycloplegic and use the retinoscope in addition to the other tests.

As a rule the ophthalmoscope should not be used before testing with the trial lenses, because if light is thrown into the eye for a prolonged time, it dazzles the sight and impairs the value of an immediate test with the trial lenses. If much trouble is experienced, however, in finding the proper glass, do not hesitate to use the ophthalmoscope to find the nature of the error of refraction, or if any pathological condition of the eye exists; then let the patient wait a short while before the subjective test with the trial lenses is again undertaken.

Simple cases of hypermetropia and myopia are, as a rule, easily fitted with glasses; but a certain definite method should be followed even in these cases. It is the astigmatic cases that give trouble, and among these, as is well known, compound hypermetropic and mixed astigmatism are the most difficult to correct.

Astigmatism is the error that should always be corrected first, unless there is a large amount of spherical error present—a myopia of 6 diopters or more, or a hypermetropia of 4 diopters or more—with only a small amount of astigmatism. In such cases, part of the spherical error is first corrected, in order, if possible, to bring up the vision sufficiently so that the eye will appreciate any further change in acuity of vision when a weak cylindrical glass is placed in front of it.

Always begin the test by putting on plus glasses; plus cylindrical glasses if astigmatism is present, plus spherical glasses if astigmatism is absent, and for the following reasons: First, because we do not know if the patient is hypermetropic or myopic. If the patient happens to be hypermetropic, plus glasses are accepted, as a rule, if first tried; however, if minus glasses are first tried, the patient many times accepts them, especially if the error is of low amount, though the patient is really hypermetropic. This is so well known that it is hardly necessary more than merely to allude to it. The eye instinctively makes an effort to overcome minus glasses when placed in front of it, the ciliary muscle is thrown into a spasm of accommodation, producing an artificial myopia, which the minus glass partially or wholly corrects, and in this way apparently improves vision. The mere fact that a patient accepts minus glasses is no indication whatever that he has myopia.

Second, the thing of most importance in beginning a test with plus glasses is, that we shall begin with the weakest lenses in the trial case and go up gradually. This is done also to avoid spasm of accommodation, for by adding a quarter of a diopter at a time the eye accustoms itself to it, and the ciliary muscle relaxes gradually if it is only given a chance. Should all, or almost all, of the correction be put on at once, however, the change for the eye is so sudden and marked that it will not adjust itself; whereas, had the glasses been gradually increased in power, the ciliary muscle would have relaxed. This is the writer's experience, and he believes it accords with that of the great majority of observers. Some ophthalmologists, however, resort to an over correction of strong plus glasses, which blur the vision completely, and thus take away the desire to accommodate for or to fix any object. Then by gradually diminishing the power of the glass, the correct one is accepted. The writer much prefers to begin with the weakest glass and "work up."

Another method of avoiding spasm of accommodation, and one well known among oculists, is to correct both eyes at the same time.

Not only should the above routine be followed, but under step No. 2 a certain routine in putting the glasses in the trial frame during the subjective tests should be adhered to. Bearing in mind always to begin the test with a plus glass (unless we know beforehand the patient to be myopic), and a *weak* plus glass, and to gradually increase the strength of the glass, in order to avoid or overcome spasm of accommodation, proceed in the following manner: When the ophthalmometer indicates astigmatism, first try plus cylindrical glasses alone; second, plus spherical glasses in addition; third, minus cylindrical glasses at right angles to the plus cylindrical glass, if vision is not made perfect by a plus cylindrical glass alone, and plus spherical glasses are not accepted in addition; fourth, minus cylindrical glasses alone; fifth, minus spherical glasses in addition. If the ophthalmometer should indicate 4 diopters of astigmatism, with the rule, 90° + or 180° —, and the patient accepts only + 2 D. cyl.

axis 90°, with improvement of vision, but accepts no plus spherical glass in addition, mixed astigmatism is at once suspected, and minus cylindrical glasses are tried at right angles to the plus cylinder.

When the ophthalmometer indicates but one-half diopter of astigmatism with the rule, usually the lenticular astigmatism neutralizes that amount of corneal astigmatism, and the patient will not accept any cylindrical glass. In such cases we are most of the time dealing with cases of simple hypermetropia and myopia, and proceed at once to try plus spherical glasses, and, if not accepted, minus spherical glasses. However, should there be only a very small amount of hypermetropia or myopia, and the patient's sight is not improved by the spherical glasses, it will be well to try a weak cylinder, plus first, then minus. This is for two reasons: first, we may have made an error with the ophthalmometer in the estimation of the amount of the astigmatism; second, the lenticular astigmatism might not be sufficient to neutralize the half diopter of corneal astigmatism, or it might more than neutralize it, when it would result in a small amount of astigmatism against the rule. Since the introduction of the Souter ophthalmophakometer the lenticular astigmatism may be measured *objectively,* and the subjective tests thus confirmed.

Illustrative cases of simple hypermetropic astigmatism and hypermetropia. In giving illustrative cases we shall first take a typical one, giving the tests for its detection and correction in detail; then other cases showing different amounts of astigmatism and different axes, and cases against and with the rule will be taken. In many cases diagrams of the sections of the eye under observation through its two chief meridians of curvature are presented.* This is done in order to have the reader think of the eye *as it is,* to see where the rays of light entering such an eye focus, and how proper glasses correct the error of refraction in such a case. Experience has shown that students at least do not think of the eye under observation, but try to fit the patient to glasses by following some empirical rule. They put on glasses by rule of thumb; if they improve vision, very well, they are satisfied with that and do not worry themselves much about the why or the wherefore; if the glasses do not improve vision, they are at a loss to know why, and many times give a wrong glass.

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* These diagrams are not meant to be mathematically correct, and are used simply to make the subject matter plainer. They are taken, together with many illustrative cases, from the writer's *Refraction of the Eye.*

Prescriptions for glasses and formulæ of lenses.

These are by no means uniform throughout the world nor even in a particular country. One ophthalmologist or optician prefers one style, quite a different one is adopted by another. In such formulæ sometimes the left eye is first mentioned; sometimes the right. Sometimes the upper semicircle is divided into 180 degrees for the purposes of the prescription, and numbered from 0 to 180°. Some authorities (in placing the figures) follow the movements of the clock hands in this numeration; others elect the reverse order. Still others divide the imaginary semicircle into two quadrants, numbering the degrees from 0 to 90° "nasal" and "temporal," the 0 in each case being placed at the extremity of the base line. Owing to this babel of method many prescription blanks are furnished with diagrams to supplement the order for glasses and especially to indicate definitely the prescribed axes of cylinders.

The formulæ most frequently used are the following. Let us suppose that the surgeon desires to prescribe (or to record) a lens for the right eye—a plus three and a half diopter sphere combined with a plus one and a half cylinder whose axis is seventy-five degrees on the *temporal* side of the vertical meridian; and for the left eye a minus two diopter sphere combined with a minus one diopter cylinder whose axis is 45°, also temporal. Let us also suppose that in another instance it is desired to order for the right eye a crossed cylinder—plus two fifty diopters axis thirty degrees, combined with minus cylinder one diopter axis one hundred and twenty, and that formula again in combination with a prism of four degrees apex directed vertically. We may begin with the *right eye* (R. E., Right, R., O. D.—*oculus dexter*—or it may be assumed by the prescriber that one should always give the formula for the right eye first); or with the *left eye* (L. E., Left, L., O. S.—*oculus sinister*—or it may be assumed that one should always give the formula of the left glass first—and so leave out the eye sign altogether!).

R. E. sph. + 3.50 D. $\overset{\frown}{\smile}$ + 1.50 D. cyl., ax. 75°.

L. E. sph. — 2.50 D. $\overset{\frown}{\smile}$ — $1._0$ D. cyl., ax. 135°.

R. E. cyl. + 2.50 D. ax. 30° $\overset{\frown}{\smile}$ cyl. — $1._0$ D., ax. 120°, $\overset{\frown}{\smile}$ pr. (or △) 4° apex vertical (or base horizontal).

The symbol D. may be omitted altogether; also (for clinical records) the visual acuity obtained by a certain lens added—thus:

V. R. E. (with, w, W., *cum* or c) sph. + 3.50 $\overset{\frown}{\smile}$ + 1.50 cyl., ax. 75° $= \frac{20}{20}$ or $\frac{6}{6}$; or the fraction to indicate the acuity of vision may be placed *below* the line at the end of the formula—thus: V. R. E. with sph. $+ 3.50 \asymp + 1.50$ cyl., ax. $75° = \frac{20}{20}$.

Another style:

$$\text{O. D.}\ \frac{\text{sph.} + 3.50}{\text{cyl.} + 1.50 \text{ ax. } 75°} = \frac{20}{20} +.\quad \text{R. E.}\ \frac{\text{cyl.} + 2.50\text{, ax. } 30°}{\text{cyl.} - 1._0 \text{ D., ax. } 120°} = \frac{20}{30}.$$

$$\text{O. S.}\ \frac{\text{sph.} - 2.50}{\text{cyl.} - 1._0 \text{ ax. } 135°} = \frac{20}{20}.$$

Inasmuch as in a prescription the abbreviation "ax." always indicates a cylinder and its absence a sphere the formulæ may be still further abbreviated:

$$\text{R.}\ \frac{+ 3.50}{+ 1.50 \text{ ax. } 75°}\qquad \text{R.}\ \frac{+ 2.50\text{, ax. } 30°}{- 1._0\text{, ax. } 120°.}$$

$$\text{L.}\ \frac{- 2.50}{- 1._0 \text{ ax. } 135°}.$$

In those clinics where the upper semicircle, divided into two quadrants of 90° each, is assumed to be held in front of each eye and the division of the quadrants into degrees begins at the extremity of the horizontal base line and proceeds towards 90° at the end of the vertical radius, the words "nasal" and "temporal" (or "n" and "t") are used to indicate the axes of prescribed cylinders:

R. E. sph. $+ 3.50 \asymp$ cyl. $+ 1.50$, ax. 75° nasal.
L. E. sph. $- 2.50 \asymp$ cyl. $- 1._0$, ax. 45° temporal.

The Editor has generally used the so-called Georges Martin style, based upon the fact that the word "sph." may always be omitted and that the sign for "degrees" always indicates a cylinder; also when one eye is indicated in the first half of the prescription it is unnecessary to indicate the second one:

$$\text{R. } 75° + 1.50 + 3.50 = 135° - 1._0 - 2.50.$$
$$= \frac{20}{15} \qquad\qquad = \frac{20}{20}$$

For brevity and definiteness this style cannot, he thinks, be improved. See, also, **Lenses, Numeration of**, p. 7407, Vol. X of this *Encyclopedia*. —*Ed.*]

Corneal astigmatism with the rule, 1 D., axis 90° + or 180° —. Patient accepts + .50 D. cyl., axis 90°.

Nellie H., aged 23, in good general health, has had trouble with her eyes for about two years. After any continuous work, especially at night, her eyes burn and ache, and often headaches follow. There is some redness of the edges of the eyelids and congestion of the conjunctiva.

Ophthalmometer. Astigmatism with the rule, 1 D., axis 90° + or 180° — in each eye.

Fig. 51 shows the general shape of the cornea, front view, in this case. Since the astigmatism is with the rule, the vertical meridian must be more curved, that is, have a shorter radius of curvature than the horizontal.

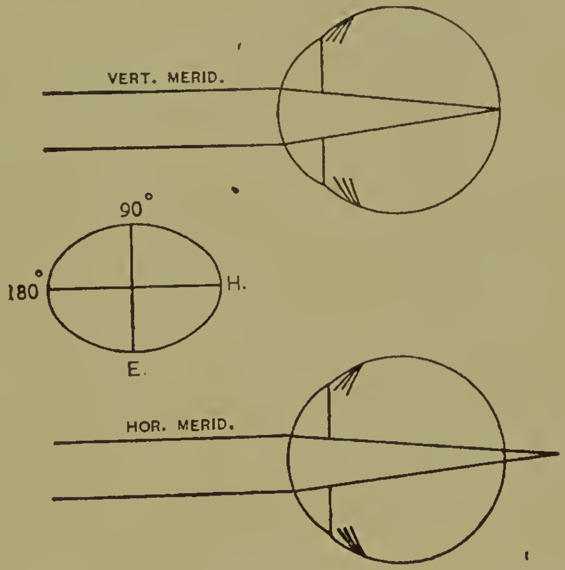

Fig. 51.

We do not know, however, from the examination with the ophthalmometer whether the error of refraction is hypermetropic or myopic in character—that must be found out by subsequent tests.

Unless from the history of the case there is reason to suspect some pathological lesion of the eye, next try the trial lenses and test cards. Do this, first, for the very good reason that most cases reveal the nature and extent of the error of refraction simply by the use of the ophthalmometer and trial lenses; second, because we do not have to delay the test with the trial lenses as we do where the ophthalmoscope is first used, for the light thrown into the eye by an extended ophthalmoscopic examination dazzles and requires some delay before the subjective test can be completed.

Test cards and trial lenses. The horizontal lines on Green's clock dial are seen plainest in this case.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 90°.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 90°.$$

Reads Jaeger No. 1 from 6 to 15 inches.

Following the rule to correct the astigmatism first, if any were present, and having proceeded with the test, as previously directed, by beginning with a weak plus glass, the first glass tried was + .25 D. cyl., 90° (as indicated by the ophthalmometer). This improved the vision somewhat, then + 50 D. cyl. ax. 90° was tried; this improved vision still more. The next stronger cyl., + .75 D., axis 90°, made the vision worse. A + .50 D. cylindrical glass, then, was the strongest cylinder that gave the best vision. To see if any manifest hypermetropia was present in addition to the astigmatism, + .25 D. spherical glass was placed in front of the + .50 D. cylindrical glass; it made vision worse, showing no manifest hypermetropia.

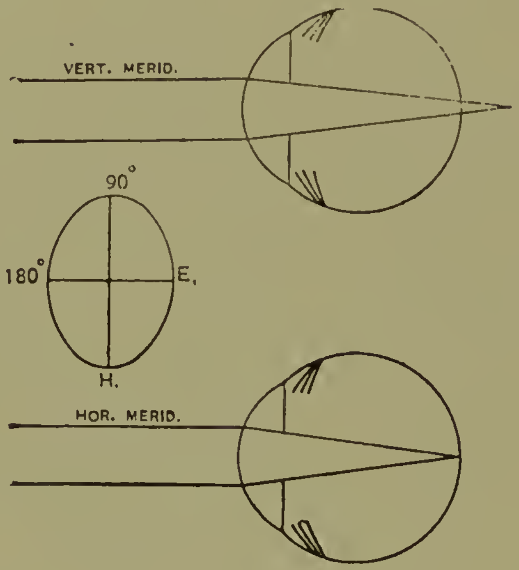

Fig. 52.

The same mode of procedure was followed in the left eye, the patient accepting a + .50 D. cylindrical glass, axis 90°, and obtaining the best vision, $\frac{20}{20}$ in each eye.

Ophthalmoscope. Hypermetropic astigmatism with the rule, .50 D., axis 90°, in each eye; no pathological lesion of the fundus in either eye.

The patient accepted the same glasses on the second test, two days later, and + .50 D. cyl., axis 90°, was prescribed.

The retinoscope and cycloplegics were not used in this case, as they were not deemed necessary. A mild astringent wash was prescribed for the slight inflammation of the lids. Three and a half years later the patient returned on account of a slight conjunctivitis. With mild astringents this was cured in three weeks' time. The glasses were still satisfactory.

Hypermetropic astigmatism against the rule, 1 D. right eye; .75 D. left eye; Patient accepts .50 D. more than the instrument reads.

L. M., aged 39, general health good. Her eyes had not given her any special trouble until last year, when they began to pain and the vision to blur when she read or sewed for any length of time. At night she had to give up close work and reading.

Ophthalmometer. Astigmatism against the rule, 1 D., axis 180° + or 90° — right eye; .75 D., axis 180° + or 90° — left eye.

Fig. 52 is a diagrammatic section of such an eye showing where the rays of light focus respectively in the vertical and horizontal meridians. The horizontal meridian is emmetropic and focuses rays on the retina; while the vertical meridian is hypermetropic, less curved than the horizontal, and allows the rays of light to focus back of the retina.

Test cards and trial lenses. The vertical lines on the Green clock-dial are seen plainest.

$$\text{R. V.} = \frac{20}{40} : \frac{20}{30} + \text{W.} + 1.50 \text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{20} + \text{W.} + 1.25 \text{ D. cyl., } 180^\circ.$$

Ophthalmoscope. Simple hypermetropic astigmatism against the rule.

On a second test the same glasses were accepted by the patient and were ordered; and these lenses were long worn with perfect satisfaction. Usually in cases of astigmia against the rule we add .50 D. to the reading of the instrument. However, it may be more or less, as illustrated by some of the following cases. Furthermore, in the cases of astigmia against the rule must be reckoned those where there is no corneal astigmatism at all, for in such cases there is usually a small amount of lenticular astigmatism against the rule which must be corrected.

No corneal astigmatism, but the patient accepts a + .50 D. cylindrical glass against the rule, at 180°.

C. C. D., aged 42 years, general health good. His eyes trouble him more or less all the time. He consulted the writer first in February, 1893, when the following condition was found:

Ophthalmometer. Shows no corneal astigmatism, that is, the images of the mires neither overlap nor separate at any position after they have once been approximated, and the black lines dividing them into halves remain opposite and straight in all positions.

In such cases it is usual for the patient to have lenticular astigmatism of about .50 D. against the rule, that is to say, if the eye is hypermetropic that a plus cylindrical glass will be worn with its axis at 180°, or in that neighborhood, while if myopic a minus cylindrical glass will be worn at 90°, or in that neighborhood.

A and B in Fig. 53 show the shape of the cornea and lens respectively, and focuses of the two chief meridians combined in the present case. A shows both meridians of the cornea to have the same radius of curvature, therefore the cornea to be spherical in shape. It is emmetropic in refractive power in this case.

The lens (B, Fig. 53) is emmetropic in refractive power in the horizontal meridian also, but in the vertical meridian it is hypermetropic by .50 D.

As both the cornea and the lens are emmetropic in the horizontal meridian, it allows the rays of light that pass through that meridian to focus exactly on the retina. The cornea is emmetropic in the vertical meridian also, but the lens is hypermetropic .50 D., and consequently the rays of light that pass through that meridian focus behind the retina. It requires a cylindrical glass of .50 D., axis 180°, to focus these rays of light on the retina; and a plus cylindrical glass worn with its axis at 180° shows the astigmatism to be against the rule; or it is possible the cornea might be .50 D. hypermetropic in all meridians (curvature H.) while the lens is .50 D. myopic in the horizontal meridian and emmetropic in the vertical; when again the patient would accept a + .50 D. cylindrical glass against the rule.

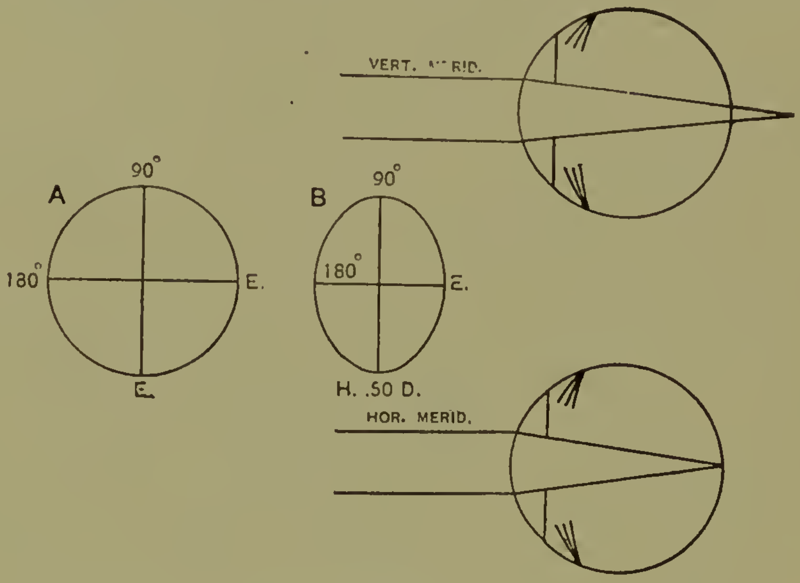

Fig. 53.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15} \text{ W. } + .50 \text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15} \text{ W. } + .50 \text{ D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 at 7 inches with a +.75 D. spherical glass added to correct the presbyopia.

Ophthalmoscope and retinoscope show hypermetropic astigmatism, .50 D. against the rule.

Ordered + .75 D. + .50 D. cyl., 180° each. Two years later the glasses were still satisfactory.

In such cases as the above the retinoscope is of value in confirming the subjective tests. In young subjects, however, to make the retinoscopic tests reliable atropin or some other cycloplegic must be used.

No corneal astigmatism. The patient accepts + cylindrical glasses against the rule at different axes, 180° and 135° respectively.

N. V., aged 14, general health first-class. For three months her eyes have troubled her greatly, and especially after studying her lessons. Blurring of the vision, pain in the eyes, and headaches are the chief symptoms she complains of. She has an older sister who has mixed astigmatism.

Ophthalmometer. No corneal astigmatism.

Retinoscope. Hypermetropic astigmatism of small amount (.50 D.) in each eye, axis of cylindrical glass 180° Rt., and at 135° (?) Lft.

Test cards and trial lenses. The vertical lines from XII to VI in the clock-dial are seen plainest by the right eye, while the lines from X to IV and XI to V are seen plainest with the left eye.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + 50\ \text{D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 135^\circ.$$

Reads Jaeger No. 1 3 to 15 inches.

Ophthalmoscope. Hypermetropic astigmatism of small amount, but could not be estimated accurately.

Figure 54 shows the form of the cornea and the foci of the chief meridians in the left eye.

On account of a mild conjunctivitis, an astringent wash for the eyes was ordered, and the patient requested to come again in one week. A cycloplegic was ordered to be used for three days before coming for the second test. The second test corresponded with the first as to the amount and axis of the astigmatism, but the patient accepted + .75 D. spherical glasses in addition to the cylinders. The ophthalmoscope and retinoscope showed compound hypermetropic astigmatism. Ordered:

+ .50 D. cyl., 180°, right eye;
+ .50 D. cyl., 135°, left eye.

One year later the glasses were still entirely satisfactory.

Corneal astigmatism with the rule. 25 D.; patient accepts + 0.25 D. cylindrical glass against the rule with improvement in vision and relief from a marked asthenopia.

Miss P., aged 19, has suffered for some time with headache, dizziness, occasional diplopia and attacks of momentary blindness. While looking out of a window at a passing parade everything suddenly appeared black to her, and she called to her sister who was in the room with her that she could not see. She felt sick and faint.

The family physician observed several of these attacks, and concluded her eyes must be at fault.

Patient is a large, healthy-looking young woman, giving history as above. Pupils normal and react properly. No apparent deviation of visual lines. *Ophthalmometer.* Astigmatism with the rule, 25 D., axis 90° + or 180° —, each eye.

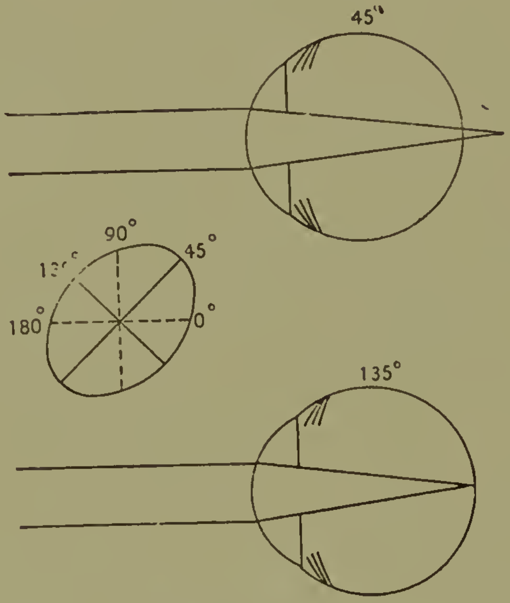

Fig. 54. Astigmatism Against the Rule, with the Axes at 45° and 135° (left eye).

Ophthalmoscope. Emmetropia each eye.

Vision, each eye $= \frac{20}{40} : \frac{20}{20}$ with + 0.25 D. cyl., ax. 180°.

Reads J. 1 with and without this glass and has good range of accommodation.

Ordered: + 0.25 D. cyl. ax. 180°, constant.

The patient is entirely free from all the asthenopic symptoms she formerly had.

The foregoing history is peculiar for two reasons: first, it is unusual for such marked symptoms to result from so small a refractive error; and second, it is unusual to have so great a diminution in vision made perfect with so weak a plus glass.

The chief thing of interest in this case from the point of view of the ophthalmometer is that the patient should wear a .25

D. cylindrical glass *against the rule* when the instrument reads .25 D. astigmatism *with the rule.* Its explanation is easy, if we only keep in mind the rule to deduct .50 D. from the reading of the instrument when the astigmatism is with the rule. In the above case there is only .25 D. of corneal astigmatism, consequently if the lenticular astigmatism is of the usual amount (.50 D.), it will not only neutralize the .25 D. of corneal astigmatism, but leave .25 D. of its own, or lenticular, astigmatism to be corrected. But why does this remaining .25 D. of lenticular astigmatism require the cylindrical glass to be worn against the rule? This can be explained better by diagrams than in any other way. A, Fig. 55, shows the cornea, front view, and the points where the rays of light passing through its chief meridians would focus if no lenticular astigmatism were present; B shows the lens, front view, and where the rays of light would focus after passing through its two chief meridians if no corneal astigmatism were present; and C represents a composite of the two as they actually are and the points where rays of light focus after passing through the two chief meridians of each.

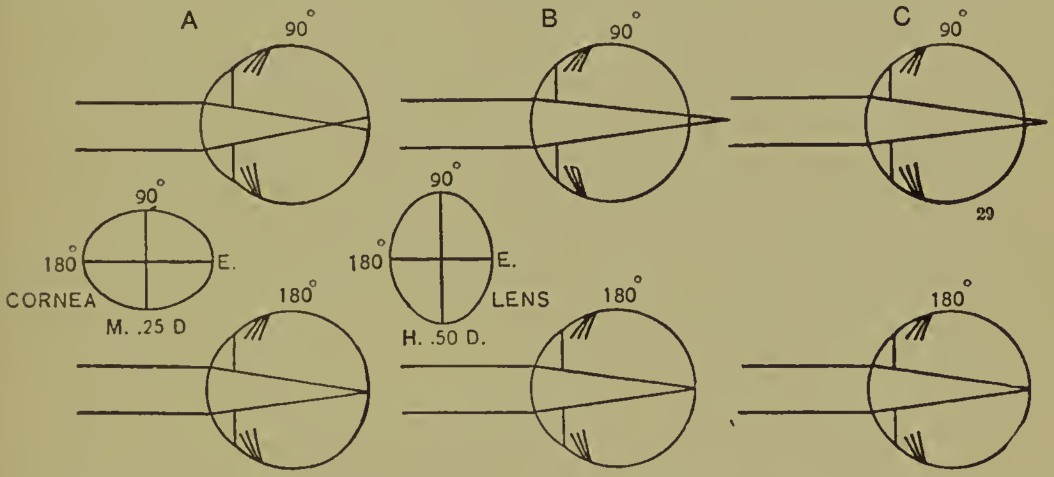

Fig. 55. *A* shows the Focuses of the Two Chief Meridians of the Cornea, assuming no Lenticular Astigmatism; *B*, the Focuses of the Two Chief Meridians of the Lens, Assuming no Corneal Astigmatism; *C*, the Focuses of Their Combined Action, with .25 D. Corneal Astigmatism with the Rule and .50 D. of Lenticular Astigmatism Against the Rule.

The horizontal meridians of both the cornea and the lens in the above cases are emmetropic, as seen by the diagrams, and allow the rays of light to focus on the retina. The vertical meridian of the cornea is more curved by .25 D. than its horizontal meridian. This is demonstrated by the overlapping of the images of the mires to the extent of .25 D. when they are turned from the horizontal to the vertical meridian after having been approximated. But the vertical meridian of the lens is too little curved by .50 D. It therefore neutralizes the .25 D. of corneal astigmatism (which is with the rule) and leaves still .25 D. lenticular astigmatism against the rule in the vertical meridian to be corrected, which requires + .25 D. cylindrical glass, axis 180°.

Cases showing the variation of axes of the chief meridians of curvature of the cornea from 90° and 180°.

The majority of cases of astigmatism have their chief meridians exactly at 90° and 180°, and, as a rule, the meridian that has the shorter radius of curvature is at 90°, while the meridian that has the longer radius of curvature is at 180°. Many times the two chief meridians are not exactly at 90°, but vary; and this variation in the majority of cases is symmetrical in character. That is, in cases of astigmatism with the rule, the shorter curved meridians slant the same number of degrees to the temporal, or nasal, side of 90° in each eye, while the longer curved meridians remain at right angles to the shorter curved meridians. For example, if the shorter curved meridian in the right eye is at 75°, that is 15° to the nasal side of 90°, the shorter curved meridian in the left eye is 105°, or also 15° to the nasal side of 90°. In other words, both axes slant inward to the extent of 15° (see Fig. 56).

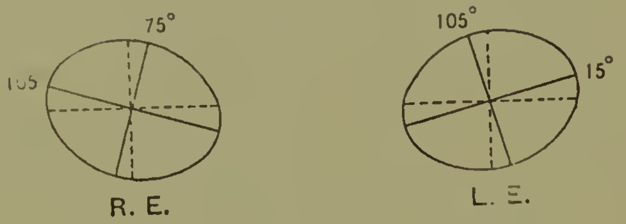

Fig. 56.

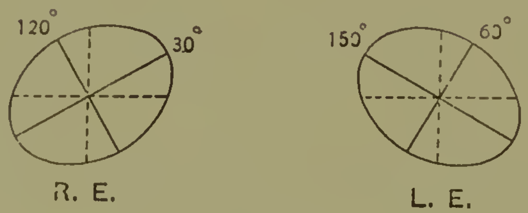

Fig. 57.

On the contrary, usually, if the shorter curved meridian in the right eye slants towards the temple 30°, the shorter meridian in the left eye slants toward the temple 30°. In such a case, the axis in the right eye would be at 120° and in the left eye at 60°, with the longer curved meridians respectively at right angles (see Fig. 57). In such a case, if the patient were hypermetropic, plus cylinders would be worn at 120° and 60°; if myopic, minus cylinders at 30° and 150°.

There are a number of exceptions to this rule, however. For instance, the meridian of shorter radius of curvature may slant but 10° to the temporal side of the vertical meridian in one eye, and 15° to the temporal side in the other, etc. Or, again, the two chief meridians of curvature may be exactly at 90° and 180° in one eye, while the chief meridians may be slanting in the opposite eye; and so on.

At rare intervals, the shorter curved meridian in each eye may slant in the same direction from the vertical meridian, that is, to the temple in one eye and to the nose in the other. For example, both of the shorter curved meridians may be at 75° (see Fig. 58).

In astigmatism against the rule the longer curved meridian is at 90° or its neighborhood, and is subject to the same variations as in the case of astigmatism with the rule.

In exceptional cases, the two chief meridians of curvature stand exactly at 45° and 135°. If this happens in both eyes, the meridian of the shorter radius of curvature is usually at 45° in one eye and at 135° in the other. The symmetry of the eyes, as indicated in the beginning of this section, is thus carried out. For each shorter meridian in this instance would slant the same number of degrees from the vetrical, both either toward the temples, or both toward the nose (see Fig. 59).

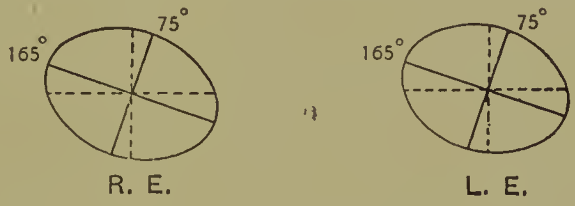

Fig. 58.

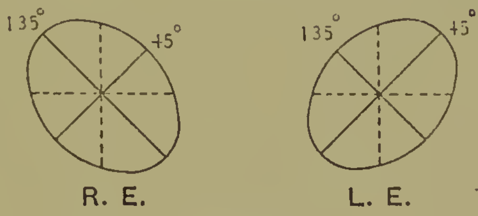

Fig. 59.

In all these cases the ophthalmometer is of inestimable value in finding the axes, and in this regard no objective method compares with it for accuracy and facility.

Both axes slant 30° to the nasal side of the vertical meridian, standing at 60° in the right eye and at 120° in the left eye.

A. R., aged 27, had worn glasses for a year, but without relief of her eye symptoms, which were pain, blurring of vision, headaches, etc. in fact typical asthenopia.

Ophthalmometer. Astigmatism with the rule, 1 D., axis 60° + or 150° — right eye; 1 D., axis 120° + or 30° — left eye.

In the present case, in the right eye, the black lines dividing the mires were not straight at 0°, but were at 150°, and that was the starting point or primary position. The mires were approximated and the indicator turned at right angles to the primary position or to 60°, where they overlapped one step. This was, therefore, astigmatism 1 D. with the rule, axis 60° + or 150° —.

In the left eye the primary position was found at 30°, and the secondary position at 120°.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{20}\ \text{W.} + .50\ \text{D. cyl., } 60^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + .50\ \text{D. cyl., } 120^\circ.$$

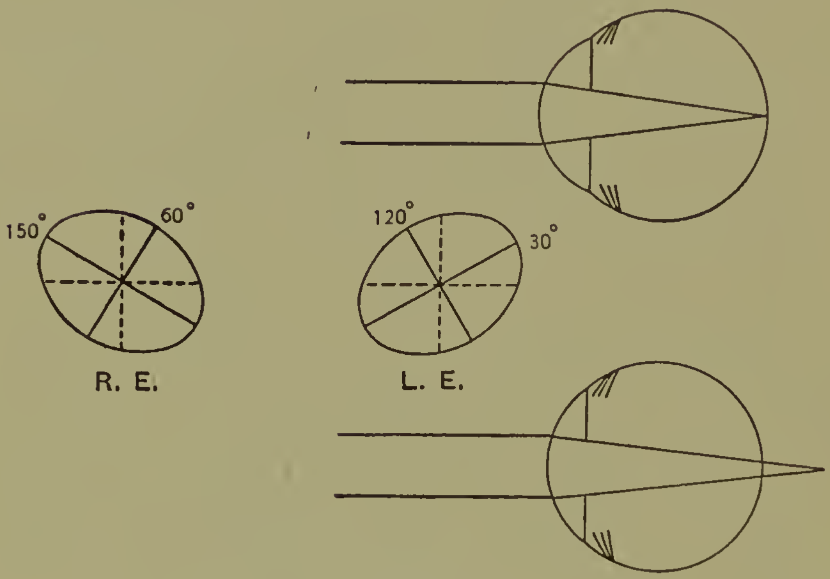

Fig. 60.

Reads Jaeger No. 1 at 6 inches.

Ophthalmoscope. Hypermetropic astigmatism in each eye.

On the second test the patient accepted the same glasses as at the first. Ordered:

+ .50 D. cyl., ax. .60° right;
+ .50 D. cyl., ax. 120° left.

Both of the shorter axes slant 15° to the temporal side of the vertical meridian, standing at 105° in the right eye and at 75° in the left eye.

H. M., aged 30, complained that the eyelids became red and swollen at times, and of frontal headaches and pains in the eyeballs. Her general health was good.

Ophthalmometer. Astigmatism with the rule, 1 D. 105° + or 15° — right eye; 1.50 D., 75° + or 165° — left eye.

Test cards and trial lenses.

R. V. $\frac{20}{30}$: $\frac{20}{20}$ W. + .50 D., cyl., 105°.

L. V. $\frac{20}{70}$: $\frac{20}{20}$ W. + 1 D., cyl., 75°.

Reads Jaeger No. 1 at 7 inches.
Ophthalmoscope. Hypermetropic astigmatism with the rule.
A second test resulted the same as the first. Ordered:
+ .50 D. cyl., 105° right eye;
+ 1 D. cyl., 75° left eye. Relief to all symptoms.

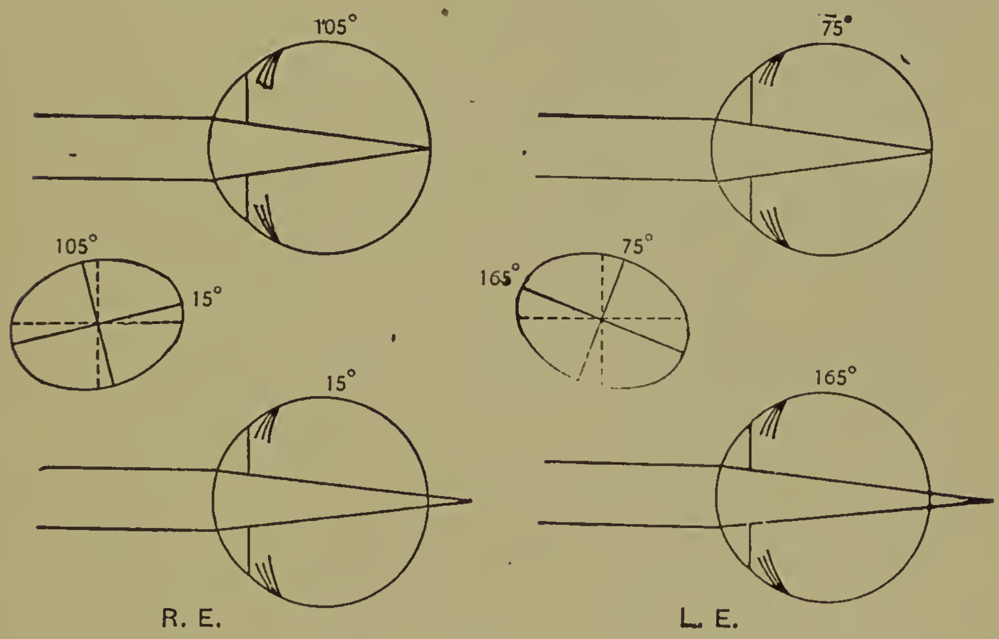

Fig. 61.

Both axes slant but 5° to the temporal side of the vertical meridian, standing at 95° in the right eye and at 85° in the left eye.

Miss F. J. O., aged 20, for two years troubled by shadows whirling around in front of her eyes. These shadows not constant, but appear at intervals and are annoying to the patient. She has no headaches and no pain in the eyes.

Ophthalmometer. Astigmatism with the rule, 1.50 D., axis 95° + or 5° — right eye; 1 D., axis 85° + or 175° — left eye.

The primary position was found at 5° and the secondary at 95° in the right eye. The primary position was found at 175° and the secondary at 85° in the left eye.

It will be noticed that in most cases of astigmatism with "off" axes, that is, with the axes away from 90° and 180°, the secondary position can be obtained by adding 90° to the primary position when that is less than 90°, and by subtracting 90° from the primary position when it is less than 90°. For instance, in this case the primary position in the right eye is at 5°, add 90° to it, and we get 95°, the secondary position. In the left eye the primary position is at 175°, subtract 90° from it, and we get 85°, the secondary position. This is true in all cases when the chief meridians are at right angles to each other, and they usually are.

Test cards and trial lenses.

R. V. $= \frac{20}{40} : \frac{20}{20}$ W. + 1 D. cyl., 95°.

L. V. $= \frac{20}{40} : \frac{20}{20}$ W. + 1 D. cyl., 85°.

Reads Jaeger No. 1 4 to 16 inches.

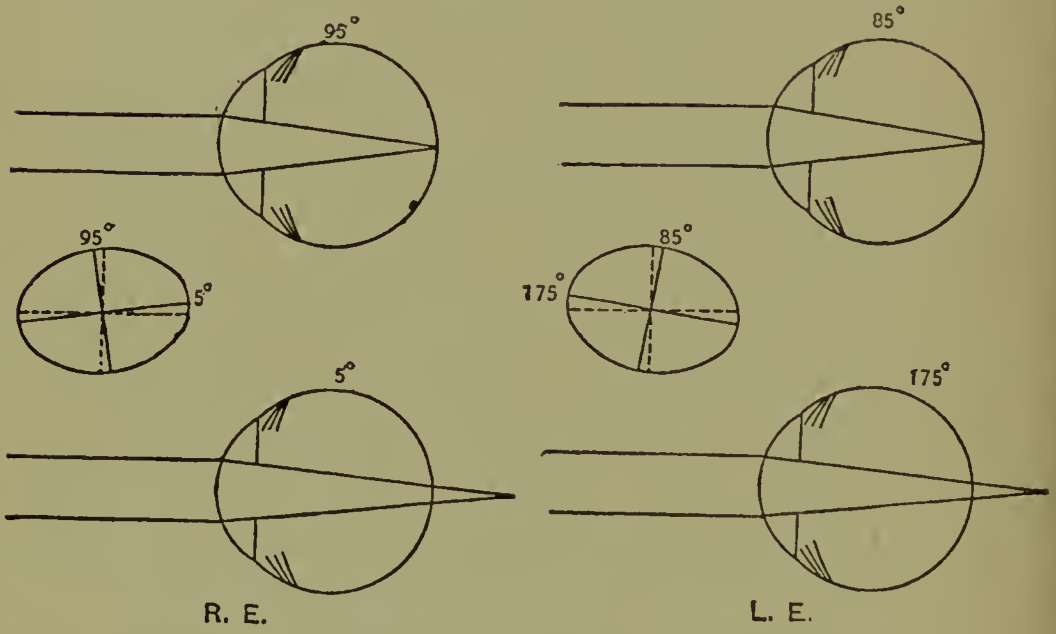

Fig. 62.

Ophthalmoscope. Simple hypermetropic astigmatism with the rule. A second test with test-cards and trial lenses resulted as follows:

R. V. $= \frac{20}{40} : \frac{20}{20}$ W. + 1 D. cyl., 95°.

L. V. $= \frac{20}{40} : \frac{20}{20}$ W. + .75 D. cyl., 85°.

Ordered:

+ 1 D. cyl., 95° right;
+ .75 D. cyl., 85° left.

Two months later the glasses were satisfactory.

Axis vertical or 90° in one eye, and 15° from the vertical in the other eye, standing at 75°.

L., aged 15, has suffered from a typical asthenopia and a mild conjunctivitis. He is in good general health, but a close student.

Ophthalmometer. Astigmatism with the rule 1 D., axis 75° + or 165° — right eye; 2.50 D., axis 90° + or 180° — left eye.

The primary position in the right eye was found at 165° and the secondary at 75°. The primary position in the left eye was found at 0° or 180° and the secondary at 90°.

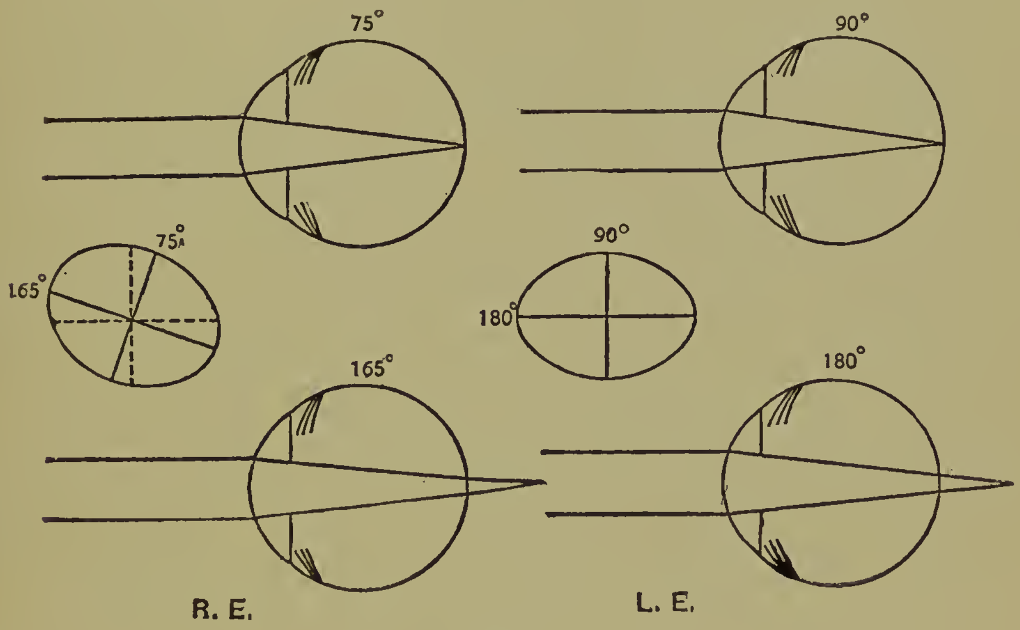

Fig. 63.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{40} : \frac{20}{20} \text{ W.} + .75 \text{ D., cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{20} \text{ W.} + 2 \text{ D., cyl., } 90^\circ.$$

Reads Jaeger No. 1 at 5 inches.

Ophthalmoscope. Simple hypermetropic astigmatism with the rule in each eye.

Ordered.

+ .75 D. cyl., 75° right;
+ 2. D. cyl., 90° left.

The glasses were satisfactory.

Both axes slant 15° in the same direction from the vertical meridian, to the temporal side in the right and to the nasal side in the left, standing in each at 105°.

R. E. P., aged 37, had frontal headaches and pains in the eyes after reading or working. His general health not very good; is a business man and overworked.

Ophthalmometer. Astigmatism with the rule 1 D., axis 105° + or 15° — in each eye. The primary position in each instance was found at 15° and the secondary at 105°.

Test cards and trial lenses.

R. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .50 D. cyl., 105°.

L. V. = $\frac{20}{20}$: $\frac{20}{15}$ W. + .50 D. cyl., 105°.

Reads Jaeger No. 1 7 to 18 inches.

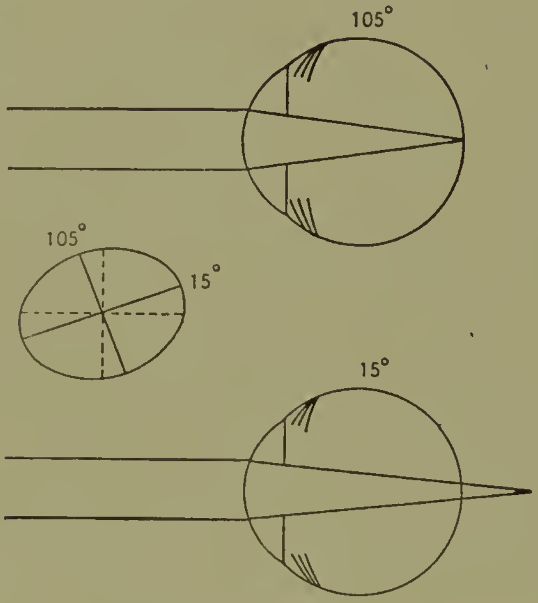

Fig. 64.

Ophthalmoscope. Simple hypermetropic astigmatism in each eye. On a second test the patient accepted the same glasses as at first. Ordered: + .50 D. cyl., 105°, each eye. These glasses continued to give relief and comfort for six months, after which the patient was lost sight of.

Astigmatism against the rule where the axes of the glasses slant relatively the same number of degrees, from the horizontal meridian, standing at 15° in one eye and at 165° in the other eye.

In hypermetropic astigmatism against the rule and myopic astigmatism with the rule, when axes vary from 90° and 180°, they usually slant the same number of degrees and relatively in the same direction from the horizontal meridian. However, there are exceptions just as numerous as the variations noted in cases of hypermetropic astigmatism with the rule, above reported, and myopic astigmatism against the rule (to be reported) in regard to the vertical meridian.

Mrs. R., aged 39, had worn glasses for a year, but her eyes continued to pain her when she did any near work. Frontal headaches, dizziness, and a drawing sensation in the eyes are the symptoms most complained of.

Ophthalmometer. Astigmatism against the rule, .50 D., axis 15° + or 105° — right eye; .25 D., axis 165° + or 75° — left eye.

The primary position in the right eye was found at 15°, the images of the mires approximated and the indicator turned to 105° when the images separated; the images were again approximated and the indicator turned back to 15°, the primary position, when an overlapping of one-half a step took place.

In the left eye the primary position was found at 165°, the secondary at 75° where the images separated. The images were again approximated and turned back to the primary position, when an overlapping of a quarter of a step took place, reading, therefore, astigmatism against the rule, .25 D., axis 165° + or 75° —.

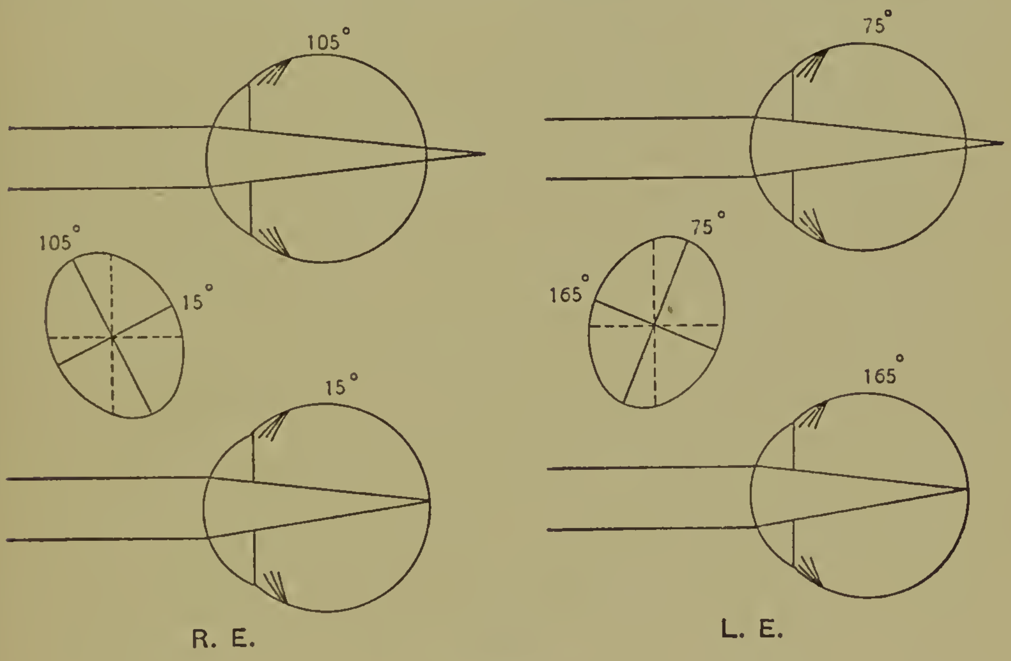

Fig. 65.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{20} + \text{W.} + 1\text{ D. cyl., } 15^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{20} + \text{W.} + .50\text{ D. cyl., } 165^\circ.$$

Reads Jaeger No. 1 at 8 inches.

Ophthalmoscope. Simple hypermetropic astigmatism against the rule each eye. Ordered:

+ 1 D. cyl., 15° right eye;
+ .50 D. cyl., 165° left eye.

Astigmatism with axes at 45° and 135°.

Annie D., aged 14, was in good health, but suffered constantly from her eyes, more when she used them for close work—a typical case of asthenopia.

Ophthalmometer. In the right eye the lines dividing the mires became straight with each other at 135° (primary position); the images of the mires were then approximated and turned to 45° (secondary position), when two steps of overlapping took place; astigmatism with the rule, 2 D., axis 45° + or 135° —. In the left eye the primary position was also found at 135°, the images of the mires approximated, and the indicator turned to 45° (secondary position), when the images of the mires separated. The images were again approximated, and the indicator turned back to the primary position at 135°, when they overlapped two steps; astigmatism against the rule, 2 D., axis 135° + or 45° —.

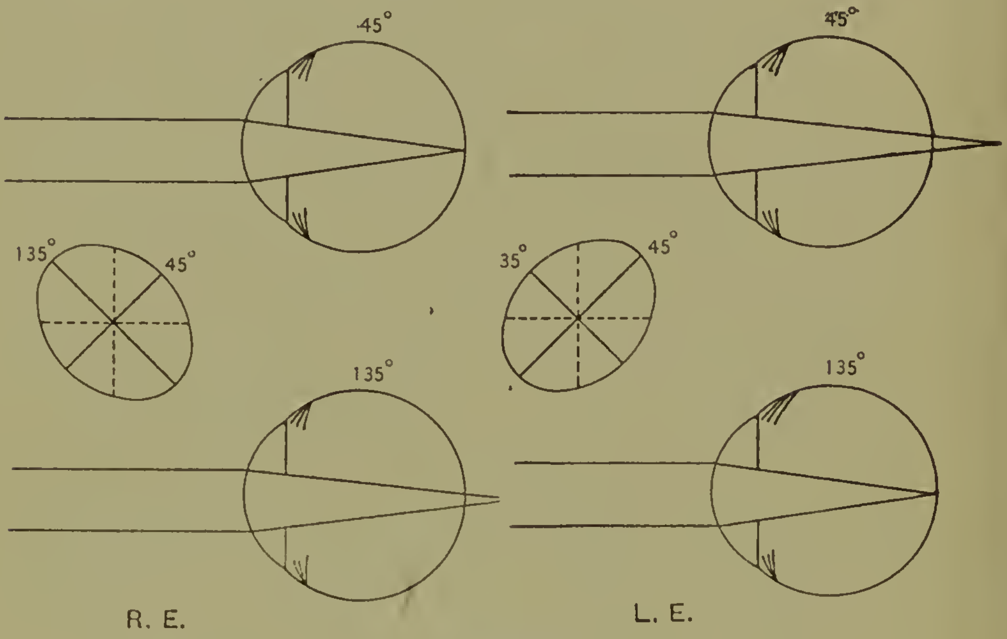

Fig. 66.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{30} \text{ W. } + 1.50 \text{ D. cyl., } 45^\circ.$$

$$\text{L. V.} = \frac{20}{50} : \frac{20}{30} \text{ W. } + 2 \text{ D. cyl., } 135^\circ.$$

Reads Jaeger No. 1 at 5 inches.

Ophthalmoscope. Simple hypermetropic astigmatism.

A second test was given and the patient accepted the same glass. Ordered.

+ 1.50 D. cyl., 45° right eye;
+ 2 D. cyl., 135° left eye.

Compound hypermetropic astigmatism against the rule; lenticular astigmatism with the rule.

The patient, æt. 44, has trouble while doing near work.

Ophthalmometer. Astigmatism with the rule, 25 D., axis 90° + or 180° —, right eye.

Astigmatism with the rule, 1 D., axis 90° + or 180° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15} + \text{W.} + .75 \text{ cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{15} : \frac{20}{15} + \text{W.} + 75 \text{ D.}$$

Reads Jaeger No. 1 from 8 to 20 inches, W. + 75 D. added.

Ophthalmoscope. H. 75 D. at 90°, and Em. at 180°, R. E. H. 1 D. L. E. Normal fundi.

Ad. 7°, ab. 3°, surs. R. & L. 1°.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15} + \text{W.} + .75 \text{ cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{15} : \frac{20}{15} + \text{W.} + .25 \text{ cyl., } 180^\circ = + .50 \text{ D.}$$

Reads Jaeger No. 1 from 8 to 20 inches with + .75 D. added.

Ordered:

$$+ .75 \text{ D.} = + .75 \text{ cyl., } 180^\circ.$$
$$+ 1.25 \text{ D.} = + .25 \text{ cyl., } 180^\circ.$$

Three months later, ophthalmometer:

(Corneal) astigmatism with the rule, .50 D., axis 90° + or 180°.
(Lenticular) against the rule, .50 D. 180° + 90° —.
right eye

(Corneal) astigmatism with the rule, 1.25 D., axis 90° + or 180° —.
(Lenticular) astigmatism against the rule, 1.50 D., axis 180° + or 90° —.
Test cards and trial lenses.
left eye

$$\text{R. V.} = \frac{20}{30} : \frac{20}{15} + \text{W.} + 1.50$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{15} + \text{W.} + 1.25 = + 25 \text{ cyl., } 180^\circ.$$

Reads Jaeger No. 1 from 8 to 20 inches, W. + 1.75 D. added.

Ad. 8°, ab. 4°, sur. R. & L. 2°.

Ophthalmoscope. H. 1.50 D. each. Ordered:
+ 3.25
+ 3. = + 25 cyl., 180°.

Hypermetropia: astigmatism with the axis at 110° in each eye.

M. M., aged 34 years, has difficulty for near work, sewing. Wearing:
+ 2.50 D., cyl., 110°.
+ 2. D., cyl., 110°.

Ophthalmometer. Astigmatism with the rule, 3.50 D., axis 110° + or 20° — right eye; 2.50 D., axis 110° + or 20° — left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{70}$: $\frac{20}{30}$ — W. + 3.00 D., cyl., 110°.

L. V. = $\frac{20}{70}$: $\frac{20}{30}$ — W. + 2.25 D., cyl., 110°.

Reads Jaeger No. 1 from 6 to 17 inches.

Ophthalmoscope: Hypermetropia, .50 D. at 110°, 4 D., at 20° right eye.

Hypermetropia, 50 D. at 110°, and 2.50 D. at 20° left eye.

Ten days later, test same. Ordered:
+ 3. D., cyl., 110°, right.
+ 2.25 D., cyl., 110°, left.

Myopic astigmatism against the rule (corneal and lenticular).

J. C., aged 25 years, complains of difficulty in reading. Wearing, right, —1.75 D. cyl., 115°; left, —1. D. cyl., 50°.

Ophthalmometer. Astigmatism against the rule (corneal) .75 D., 30° + or 120° —.
Astigmatism against the rule (lenticular) .75 D., 30° + or 120° —. } right eye

Astigmatism against the rule (corneal) .75 D., 150° + or 60° —.
Astigmatism against the rule (lenticular) .50 D., 150° + or 60° —. } left eye

Test cards and trial lenses.

R. V. = $\frac{20}{40}$: $\frac{20}{15}$ + W. — 1.37 cyl., 120°.

L. V. = $\frac{20}{40}$: $\frac{20}{15}$ — W. — 1.00 cyl., 55°.

Reads Jaeger No. 1 from 6 to 18 inches.
Ad. 15°; ab. 4°; sur. R. & L. 2°.

Ophthalmoscope shows H. 1.50 D. at 30°, and E. at 120°, R. E.: M 1. D. at 150° and E. at 60° L. E.

Ordered:

— 1.37 cyl., 120°.
— 1 cyl., 55°. Satisfactory.

CHAPTER X.

COMPOUND HYPERMETROPIC ASTIGMATISM—SPASM OF ACCOMMODATION—ILLUSTRATIVE CASES.

To emphasize the importance of correcting the astigmatism, first, if there happens to be only a simple astigmatism present, we have gone to the root of the trouble at once; and if a spherical error is present in addition to the astigmatism, we have disposed of the astigmatism and have only the spherical error left to deal with, as in simple hypermetropia and myopia. This method of procedure is of great advantage when there is a tendency to spasm of accommodation: for after the astigmatism has been corrected in each eye separately, we can then put spherical glasses before both eyes at once. In this way, as is well known, the tendency to spasm of accommodation is overcome, and the patient many times accepts stronger plus, or weaker minus, glasses than when one eye is tested at a time. However, it should not be forgotten that spherical glasses should be tried in addition to the cylindrical glasses on each eye separately, before both eyes are tried together, for there may be more spherical error in one eye than the other. For example, say the patient accepts in the right eye + 1 D. + 2 D. cyl., 90°, and in the left eye + .50 D. + 2 D. cyl., 90°, when each eye is tested separately. If we suspect spasm of accommodation, we should leave the cylindrical glasses as they are and place in front of them at the same time a + .25 D. stronger spherical glass than they accepted singly. In this instance, in front of the right eye + 1.25 D. and in front of the left + .75 D. If these are accepted, add + .25 D. stronger sphere and so continue till the vision begins to be made worse.

In compound hypermetropic astigmatism, spasm of accommodation is more often present perhaps than in any other error of refraction.

Amblyopia, which is often present in high degrees of compound hypermetropic astigmatism, is often a stumbling-block for beginners, on account of which they often use a cycloplegic when none is called for. In such cases, not being able to improve the vision much with any glass, they think perhaps it is their own fault in not fitting the glasses correctly that the patient does not obtain better vision, not stopping to consider that amblyopia may be present, and that no glass whatever will give better vision. They accordingly use a cycloplegic, but find after all that the patient cannot be made to see any better with the glasses accepted under the use of a cycloplegic than with those accepted at first. They have simply had their trouble for nothing, besides giving the patient great inconvenience.

The writer's practice in such cases is to give two tests on different days; if the second test corresponds with the first the glasses that are accepted are ordered, though they do not improve the vision much. By the use of the ophthalmometer we know if any corneal astigmatism is present or not, and, if present, its axis and amount. With this important point ascertained we know approximately beforehand what cylindrical glass the patient should accept and do not have to depend so much on his answers. After the astigmatism is once corrected, the spherical part of the error is corrected with comparative ease. If the two tests do not agree, and if there is a question of spasm of accommodation, do not hesitate to use a cycloplegic and a strong one. Afterwards, retinoscopy may be brought to the aid of the other tests. The phakometer should be used along with the other objective tests.

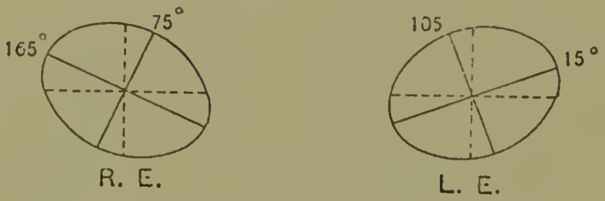

Fig. 67.

The following cases serve to bring out the points mentioned above.

Large amount of astigmatism with the axis slanting relatively the same number of degrees from the vertical meridian, 15° to the nasal side, in each eye; Patient accepts a compound plus glass with relief of asthenopic symptoms.

M. D., aged 24, in good health, but her eyes ache after she uses them for a short time for close work, especially in the evening.

Ophthalmometer. Astigmatism with the rule, 3 D., axis 75° + or 165° — right eye; 3 D., axis 105° + or 15° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{70} : \frac{20}{40}\ \text{W.} + 3\ \text{D.} + 2.50\ \text{D. cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{40}\ \text{W.} + 3\ \text{D.} + 2.50\ \text{D. cyl., } 105^\circ.$$

Reads Jaeger No. 1 from 6 to 17 inches.

Ophthalmoscope. Hypermetropia 3.50 D. at 75° and 6.50 D. at 165° right eye; and 3.50 D. at 105° and 6.50 D. at 15° left eye.

The lines on the clock-dial from X to IV were seen best with the right eye, and from II to VIII with the left eye. The simple cylindrical glass before each eye served to bring out all the lines on the clock-dial equally clear, indicating that the astigmatism had been corrected. On a second test the patient accepted exactly the same glasses as on the first test, and they were ordered, and have been worn with comfort ever since. See p. 2297, Vol. III of this *Encyclopedia.*

Astigmatism against the rule, 1 D., with the axis 15° from the horizontal meridian in each eye; Patient accepts compound plus glasses and gets relief from asthenopia.

Mrs. C. W. T., age 39, in good general health, came for glasses on account of painful vision and headaches. The pupil in the left eye was dilated for some weeks when she was a child, from some unknown cause. There is no history of scarlet fever, diphtheria or any serious illness. The pupils are normal in size and reactions.

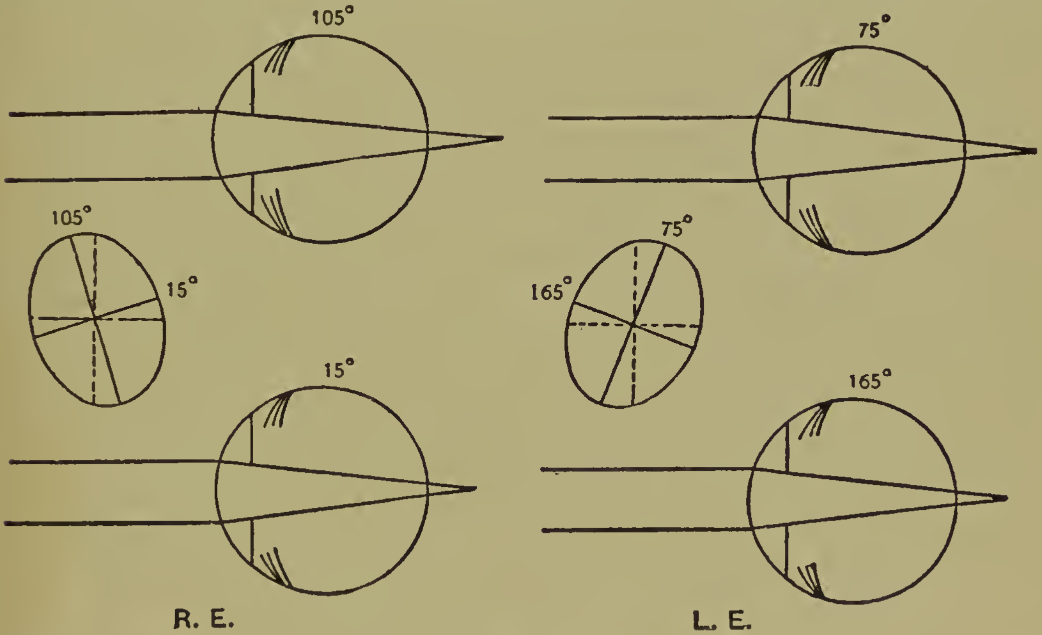

Fig. 68.

Ophthalmometer. Astigmatism against the rule, 1 D., axis 15° + or 105° — right eye; 1 D., axis 165° + or 75° — left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{30} : \frac{20}{15}$ W. + 1 D. + 1 D. cyl., 15°.

L. V. = $\frac{20}{30} : \frac{20}{15}$ W. + .75 D. + 1 D. cyl., 165°.

Reads Jaeger No. 1 8 to 18 inches, each eye.

Ophthalmoscope. H. 2.50 D. at 105° and 1.50 D. at 15°, right eye; H. 2.50 D. at 75° and 1.50 D. at 165°, left eye.

On a second test, three days later, the patient accepted exactly the same glass in the left eye and a quarter diopter weaker spherical glass in the right. Ordered:

+ .75 D. + 1 D. cyl., 15° right;
+ .75 D. + 1 D. cyl., 165° left.

Small amount of astigmatism associated with a large amount of hypermetropia; Marked asthenopia: Relief with glasses.

Miss M. H., aged 35, in good health, has worn glasses for six years. The vision blurs after reading for a few moments, and she has to stop and rub the eyes before she can continue.

Ophthalmometer. Astigmatism with the rule, 1.25 D., axis 90° + or 180° — right eye; 1.25 D., axis 105° + or 15° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{40}\ \text{W.} + 4\ \text{D.} + .75\ \text{D. cyl., } 90^\circ.$$

$$\text{L. V.} = \frac{20}{200} : \frac{20}{40}\ \text{W.} + 4\ \text{D.} + .75\ \text{D. cyl., } 105^\circ.$$

Reads Jaeger No. 1 7½ to 17 inches.

Ophthalmoscope. H. 4 D. at 90° and 5 D. at 180° right eye; H. 4 D. at 105° and 5 D. at 15° left eye.

A second test resulted in the patient accepting exactly the same glasses as at the first test, and they were ordered. They have been worn four years, with entire relief of asthenopic symptoms.

The point of interest in this case, as far as fitting the glasses is concerned, is the order of sequence in which the glasses should be placed in the trial frames during the test. That is, if cylindrical glasses should be tried first, or spherical glasses. The writer (*N. Y. Med. Journ.*, June 20, 1896) believes that in cases of compound astigmatism it is always best to correct the astigmatism first, unless there is a large amount of spherical error present—a hypermetropia of 4 D. or more, a myopia of 6 D. or more, with only a small amount of astigmatism present. In these cases, complicated with an astigmatism of as much as 1 D., the cylindrical glass will be appreciated and vision improved to a slight extent with it alone, and before the spherical glass is added. The tendency in such cases (large amount of spherical error associated with small amount of astigmatism) where the cylindrical glasses are tried first, is for the patient to accept too strong cylindrical glasses. We are careful in such cases, at the close of the test, to weaken the cylindrical glasses slightly and at the same time to increase the strength of the spherical glasses a little, to see if the vision is improved by the change. If it is, we make the change; if not, we give the original glass as first accepted. Mention of this fact here is for the benefit of beginners and because it is a point of practical importance. On the other hand, for those who make it a habit to correct the spherical error first, that the reverse condition holds; that is, the patient is liable to accept too strong a spherical glass relative to the cylindrical glass. In such case it is well to weaken the spherical glass at the close of the test and at the same time increase the strength of the cylindrical glass to find if vision can be improved.

Again, in such cases as the one reported, the patient may accept the cylindrical glass as indicated by the ophthalmometer without either improving or making the vision worse. Then leave the cylindrical glass on and proceed to correct the spherical error. When this is corrected, you will find that the vision is made worse if the cylindrical glass is removed, though while the cylindrical glass was on alone it seemed not to affect the vision one way or the other. This is easily accounted for. The spherical error being large, and the astigmatism being small, the cylindrical glass while on by itself has but little appreciable effect, but when the spherical error is corrected (if there is not a marked amblyopia present), the vision is brought up to something like the normal, and the eye can then appreciate the presence or absence even of a weak cylindrical glass, which it could not do at first.

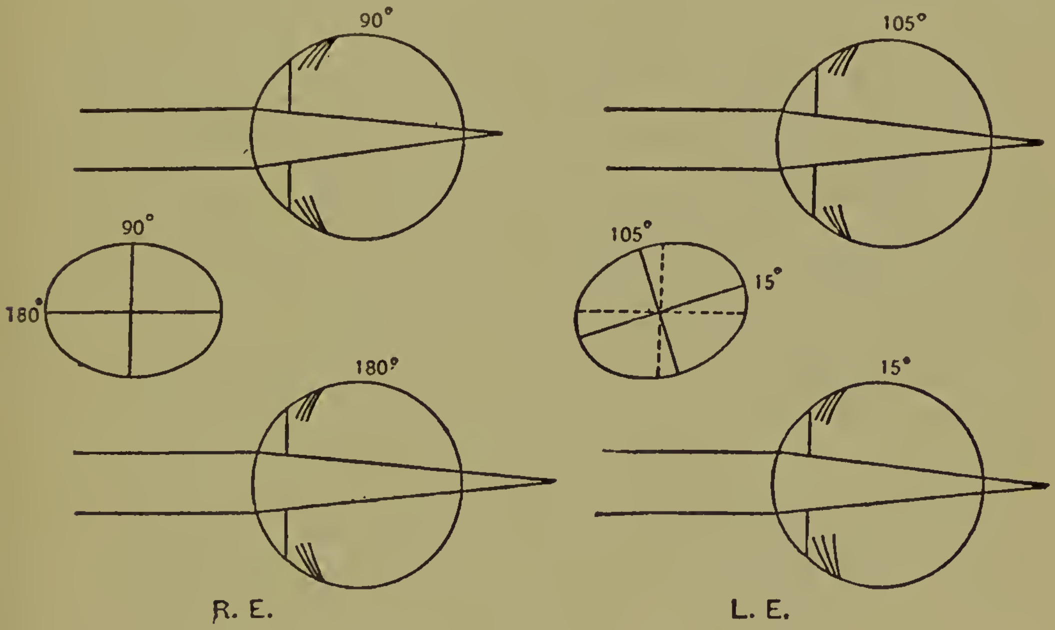

Fig. 69.

Hypermetropic astigmatism in each eye of equal amount, 2 D.; Patient accepts a simple plus cylindrical glass in one eye, and a compound plus glass in the other; Relief from asthenopia.

D., aged 25, has good general health, but has had weak eyes since childhood. After any close work she has headaches and pains in the eyes, especially the left eye.

Ophthalmometer. Astigmatism with the rule, 2 D., axis 75° + or 165° — right eye; 2 D., axis 120° + or 30° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{70} : \frac{20}{30} \text{ W. } + 1.75 \text{ D. cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{30} \text{ W. } + 1.50 \text{ D. cyl., } 120^\circ.$$

Reads Jaeger No. 1 5½ to 17½ inches.

Ophthalmoscope. H. 2 D. at 165° and emmetropia at 75° right eye; H. .50 D. at 120° and H. 2 D. at 30° left eye.

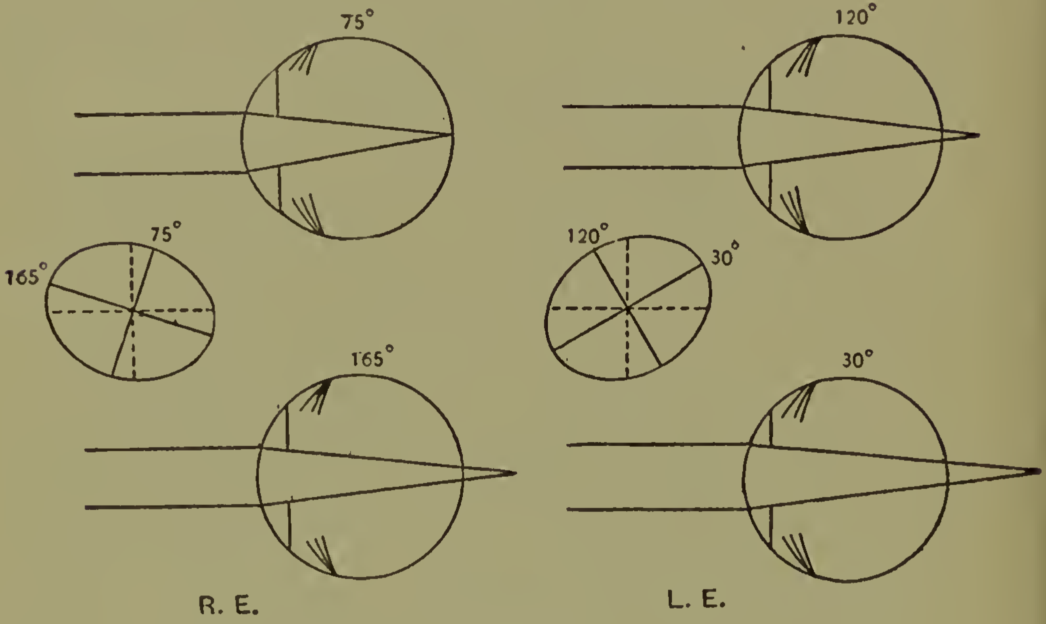

Fig. 70.

Two days later a second test was made. The ophthalmometer read exactly the same, both as to the axis and amount of the astigmatism in the left eye as at the first test, and the same axis, but .50 D. more in amount, for the right eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{70} : \frac{20}{20} \text{ W. } + 2 \text{ D. cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{20} \text{ W. } + .50 \text{ D. } + 1.50 \text{ D. cyl., } 120^\circ.$$

Reads Jaeger No. 1 5½ to 17½ inches.

These glasses have been worn constantly with relief.

Compound hypermetropic astigmatism against the rule in one eye; Large amount of hypermetropia in the other eye; Marked asthenopia; Relief with the use of glasses.

F. D. M., aged 21, in poor general health, and is very nervous and easily excited or depressed. Her mother was a very nervous woman also. The patient suffers much from fatigue and often has headaches, and her eyes pain after any close work or reading. There is a mild conjunctivitis.

Ophthalmometer. Astigmatism against the rule, .25 D., axis 30° + or 120° — right eye; astigmatism with the rule, .50 D., axis 90° + or 180° — left eye.

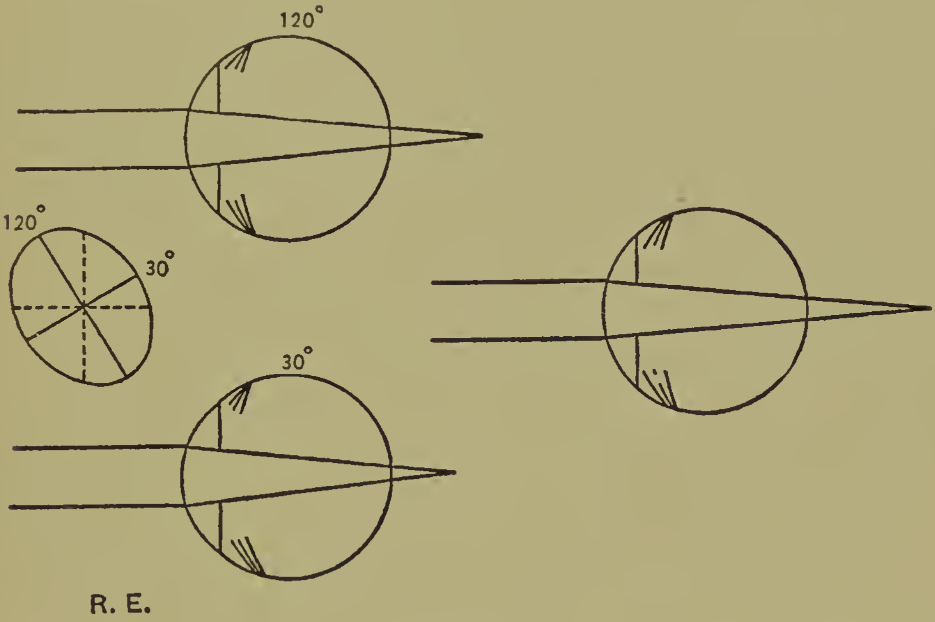

Fig. 71.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{20}\ \text{W.} + 3\ \text{D.} + .75\ \text{D. cyl., } 30^\circ.$$

$$\text{L. V.} = \frac{20}{200} : \frac{20}{100}\ \text{W.} + 6\ \text{D.}$$

Reads Jaeger No. 1 at 6 inches with the right eye, Jaeger No. 4 at the same distance with the left eye.

Ophthalmoscope. D. 4 D. at 120° and 3 D. at 30° right eye; H. 7 D. left eye.

The second test resulted in the patient accepting the same glasses as at the first test, and they were accordingly ordered. She wore these glasses for eighteen months with great comfort, though at times she suffered from headaches when greatly exhausted. Her general health improved considerably, but she is still easily excited.

Compound hypermetropic astigmatism with the chief meridians of curvature at 45° and 135°; Marked asthenopia; Relief with glasses.

B. F., aged 39, in good general health, has had "weak eyes" since childhood. When thirteen years old she had "drops," salve, and glasses prescribed. She had but little trouble after that until eight years ago, when the eyes became painful, the eyelids red, and troublesome headaches followed, after using the eyes for close work.

Ophthalmometer. Astigmatism against the rule, 75 D., axis 135° + or 45° — right eye; astigmatism with the rule, 75 D., axis 45° + or 135° — left eye.

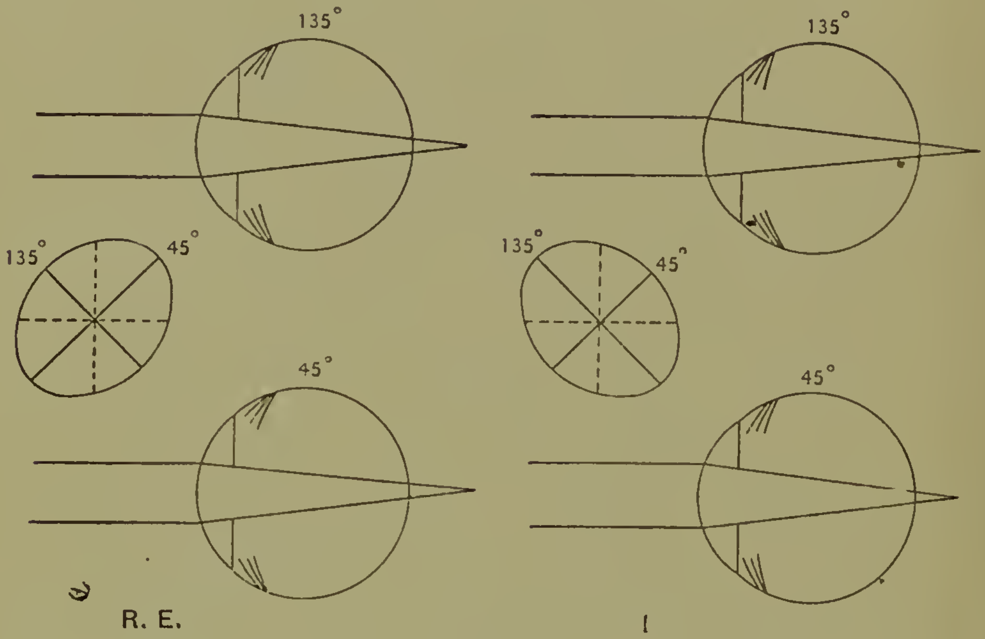

Fig. 72.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{15} : \frac{20}{15} \text{ W.} + .75 \text{ D.} + .25 \text{ D. cyl., } 135^\circ.$$

$$\text{L. V.} = \frac{20}{15} : \frac{20}{15} \text{ W.} + 1 \text{ D.} + .25 \text{ D. cyl., } 45^\circ.$$

Reads Jaeger No. 1 7½ to 18 inches.

Ophthalmoscope. Hypermetropia of 1.50 D. in each eye. It was impossible to estimate the small amount of astigmatism.

Second test, three days later, resulted as follows: Ophthalmometer gave the same reading as on the previous examination.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{15} : \frac{20}{15} \text{ W.} + 1.25 \text{ D.} + .25 \text{ D. cyl., } 135^\circ.$$

$$\text{L. V.} = \frac{20}{15} — : \frac{20}{15} \text{ W.} + 1.25 \text{ D.} + .25 \text{ D. cyl., } 45°.$$

The ophthalmoscope showed the same amount of H. as at the first examination. Ordered:

+ 1.25 D. + .25 D. cyl., 135°;
+ 1.25 D. + .25 D. cyl., 45°.

These glasses were worn constantly for three and one-half years and with entire relief of her blepharitis marginalis and freedom from asthenopia. At the end of this time + 50 D. was added to the glasses for reading purposes, on account of presbyopia.

Here again the ophthalmometer was of great assistance, for it pointed out the small amount of astigmatism that was present and at the unusual axes of 45° and 135°, which astigmatism, by the way, had been overlooked at her previous tests under a cycloplegic. The instrument read astigmatism against the rule in the right eye and with the rule in the left eye, and an equal amount in each, .75 D. In the right eye, instead of adding .50 D. to the reading of the instrument, as is usual in cases of astigmatism against the rule, .50 D. had to be deducted, just as in the left eye, where the astigmatism was with the rule. It must be remembered that, when the chief meridians of curvature are at 45° and 135°, the exact halfway points between 0° and 90° on one side, and 90° and 180° on the other side of the 90°, the terms "with the rule" and "against the rule" do not strictly hold, for the meridians at these points are just as near to 90° as they are to 180°. In other words, they are on the dividing lines between astigmatism with the rule and astigmatism against the rule. Consequently the usual addition of .50 D. to the reading of the instrument, as in astigmatism against the rule, and the subtraction of .50 D. from it, as in astigmatism with the rule, does not hold very strictly in these cases. Knowing the axis of the astigmatism, however, the amount of it, even were it not indicated by the instrument, is usually easily obtained by subjective tests with the trial glasses, especially if the method of beginning the test with the weakest plus glass and gradually increasing it in strength is followed. For instance, in this case we began the subjective test, right eye, with + .25 D. cylindrical glass, axis 135°, which was accepted with improvement in the vision. Then + .50 D. cyl., same axis, was tried, but not accepted. Then + .25 D. sphere was added to the + .25 D. cyl., which improved vision. The spherical glass was increased in strength + .25 D. at a time, till the patient accepted + 1.25 D.s in addition to the .25 D. cyl., axis 135°, which gave her the best vision. Exactly the same course was pursued with the left eye. The phakometer and retinoscope should be used in all doubtful cases, after a cycloplegic has been instilled.

Astigmatism against the rule in one eye and with the rule in the other; Marked asthenopia; Relief with glasses.

Mr. C. C., aged 47, in moderately good health, has been unable to get suitable glasses. The patient received a blow on his right eye with a rubber ball when he was a child, and has never seen very well with that eye since.

Ophthalmometer. Astigmatism against the rule, .50 D., axis 155° + or 65° — right eye; astigmatism with the rule, .75 D., axis 105° + or 15° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{70} : \frac{20}{50} \text{ W.} + 1 \text{ D.} + 1 \text{ D. cyl., } 155^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15} \text{ W.} + .50 \text{ D.} + .25 \text{ D. cyl., } 105^\circ.$$

Reads Jaeger No. 1 at 8 inches with + 1.50 D.s added to correct the presbyopia.

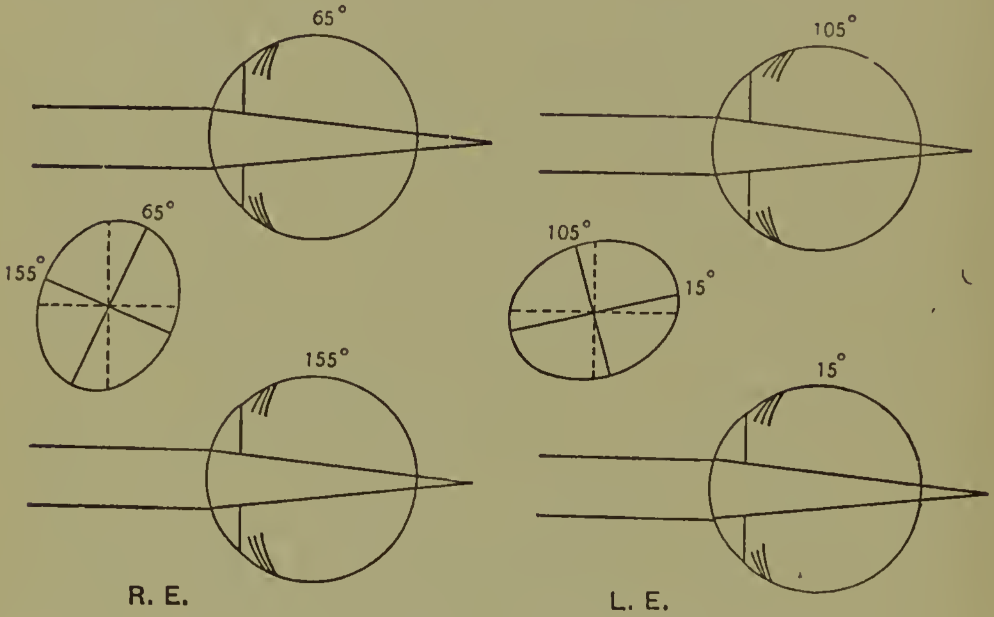

Fig. 73.

Ophthalmoscope. H. 2 D. at 65° and 1 D. at 155° right eye; H 1 D. left eye, the astigmatism being too small to estimate with the ophthalmoscope.

The patient accepted the same glasses on a second test that he accepted at first, and both reading and distance glasses were ordered. These glasses have been entirely comfortable, though he has used his eyes continuously in the capacity of a teacher. He was wearing when he came under care a cylindrical glass at the wrong axis in the right eye, and in the left eye a cylindrical glass four times too strong, which were very good reasons for not having comfortable eyes and good vision.

Ophthalmometer shows corneal astigmatism with the rule, .25 D.; Patient accepts this amount exactly, indicating no lenticular astigmatism whatever.

J. E. H., aged 21, in good health, has worn glasses for the last four years, but suffers continually with pains in the eyes, headaches, and nervousness. He is a bookkeeper, and the strain on his eyes is great.

Ophthalmometer. Astigmatism with the rule, .25 D., axis 105° + or 15° — right eye; .25 D., axis 75° + or 165° — left eye.

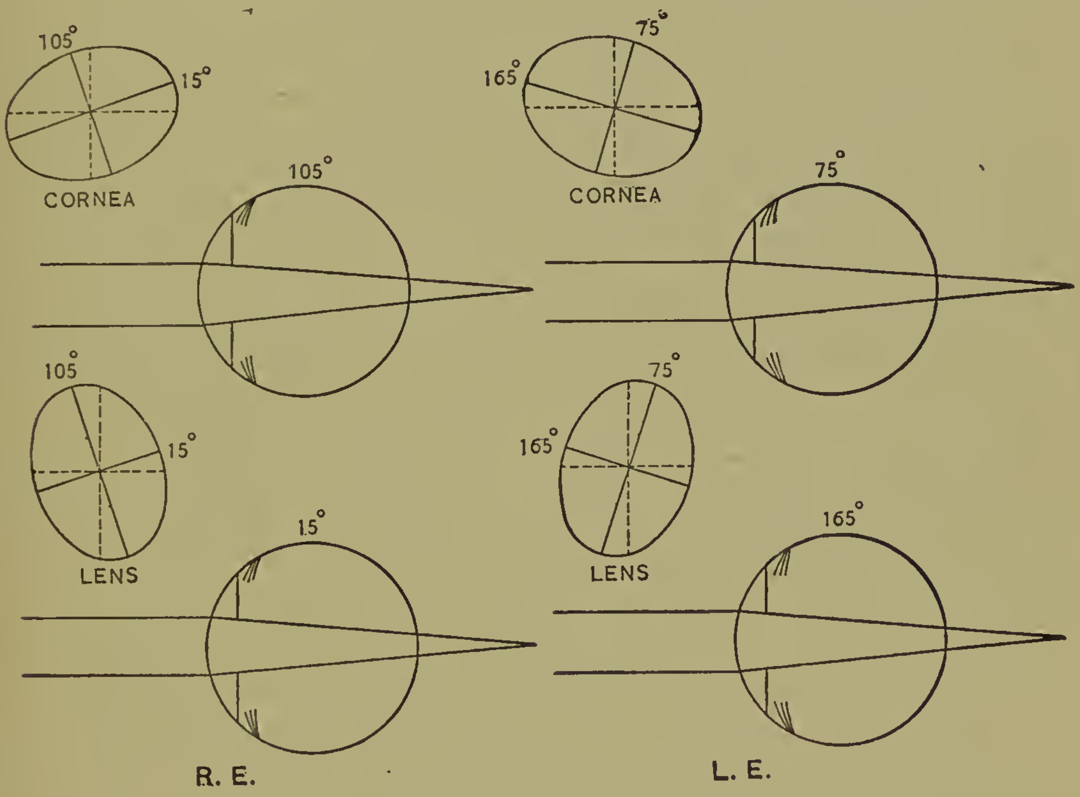

Fig. 74.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + 50\ \text{D.} + .25\ \text{D. cyl., } 105°.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + 50\ \text{D.} + .25\ \text{D. cyl., } 75°.$$

Reads Jaeger No. 1 at 5 inches.

Ophthalmoscope. H. 1 D. in each eye.

On the second test, the same glasses were accepted, and were ordered. With these glasses he could follow his calling as a bookkeeper, with comfort.

Astigmatism with the rule, .25 D.; Patient accepts .50 D. cylindrical glass against the rule, in combination with 2 D.s; Latent hypermetropia of 2 D. left uncorrected; Marked asthenopia; Relief with glasses.

W. E., aged 20, in good health, family history good, has been troubled with his eyes since a child. Has headaches, and pains in the eyes after close work of any kind.

Ophthalmometer. Astigmatism with the rule. .25 D., axis 105° + or 15° — right eye; 25 D., axis 75° + or 165° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{15} \text{ W.} + 1.50 \text{ D.} + .50 \text{ D. cyl., } 15^\circ.$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{15} \text{ W.} + 1.50 \text{ D.} + .25 \text{ D. cyl., } 165^\circ.$$

Reads Jaeger No. 1 at 7 inches.

Ophthalmoscope. H. 4.50 D. at 105° and 4 D. at 15° right eye; H. 4.50 D. at 75° and 4 D. at 165° left eye.

On account of the large amount of latent hypermetropia present in this case, three tests were given, each time correcting the astigmatism in each eye, separately; then we placed equal spherical glasses in front of each eye at the same time, beginning with + .25 D., and gradually increased their strength up to 2 D., which were as strong as the patient would accept. This spherical glass, in conjunction with the cylindrical ones gave him $\frac{20}{15}$ vision, and they were ordered. Although 2 D. of latent hypermetropia remained uncorrected, these glasses were worn for two and one-half years with entire relief from his asthenopic symptoms. In passing, it might be remarked that there was no insufficiency of any of the ocular muscles, and no tendency to squint.

CHAPTER XI.

SPASM OF ACCOMMODATION.

Spasm of the accommodation may be present in any form of error of refraction, but it is met with more frequently in hypermetropia, hypermetropic astigmatism, and mixed astigmatism than in myopic cases. Fortunately, spasm of the accommodation is a comparatively rare condition, and the instances in which (except strabismic cases) it is necessary to use a cycloplegic to suspend the accommodation are relatively few.

In support of this statement the reader is referred to papers by Roosa (*Trans. Med. Soc., State of New York*, Feb., 1891), George J. Bull (*Ophthalmic Review*, Sept., 1895), of Paris, and the writer (*New York Medical Journal*, Sept. 10 and October 8, 1892, and June 20, 1896) and of American and European ophthalmologists in general during the last few years.

[However, the majority of American text books agree with the views expressed by Ball (*Modern Ophthalmology*, p. 731, 1916) that "this constant contraction of the ciliary muscle frequently produces a *spasm of the accommodation*, especially in neurasthenic individuals with hyperopia, giving rise to annoying blurring of distance vision. Both the near and the far point are brought nearer the eye, and vision is improved by concave lenses, which, of course, should never be ordered, as they would only increase the trouble. The condition simulates myopia, and might be mistaken for such by a careless observer, *unless the eye is brought thoroughly under the influence of a cycloplegic."—Ed.*]

It is not necessary to use a cycloplegic in *every* case of spasm of accommodation; for, in many instances, if the cause is found and removed, the spasm disappears. Two questions of importance are to be considered in discussing spasm of accommodation: first, how to recognize it; second, how to treat it, especially in regard to fitting glasses.

How to recognize spasm of accommodation. The most important of the *subjective* symptoms are: (1) Sudden variability in vision in reading the test cards for distant vision. For example, testing one eye at a time, the patient reads all of the letters on the Snellen card down to and including the $\frac{20}{30}$ line perhaps, when suddenly the letters fade out, and the patient is not able to read more than $\frac{20}{100}$ or even less. Allow the patient to rest a moment with the eyes closed, then repeat the test, and the same thing will likely happen again. This condition may be present in only one eye, but usually it occurs in both, if present at all. This sudden failure of the vision is evidently due to sudden contraction or spasm of the ciliary muscle, which allows the crystalline lens to expand, and the eye to become temporarily myopic (false or spasmodic myopia). This condition, of course, makes the distant vision bad.

(2) Changeableness of the lines on the clock-dial. For instance, say we have a case of simple hypermetropic astigmatism with the

rule, and a tendency to spasm of accommodation. This patient when he first looks at the clock-dial may see the horizontal lines plainest (as he should if no spasm of accommodation is present), but in a moment the vertical lines appear plainest and the horizontal lines become dim. Evidently in such case the spasm of the ciliary muscle has converted the simple hypermetropic astigmatism into a myopic astigmatism with the rule, for in myopic astigmatism with the rule the vertical lines are seen plainest. (3) A sense of contraction or drawing in the eyeball is felt. (4) Variability in the glass accepted by the patient during the test, e. g., a patient accepts a plus glass one minute and in the next refuses it, or, perhaps, accepts a minus glass, quickly changing from one to the other; or he may accept a strong plus glass one minute and only a weak one the next.

The *objective* symptoms are: (1) Where the ophthalmoscopic examination shows the refractive condition of the eye to be widely different from the glasses accepted on subjective examinations. For instance, the patient has accepted + 1 D. spherical glasses when the ophthalmoscope shows him to be hypermetropic by 5 D. Or, say the patient has accepted — 1 D. spherical glasses when the ophthalmoscope shows him to be actually hypermetropic. Not infrequently the patient will relax his spasm of accommodation under an ophthalmoscopic examination when he will not under a subjective examination. This is due chiefly to the fact that under an ophthalmoscopic examination the patient is in a dark room, with pupils dilated, and looking in the distance at nothing in particular, having nothing, therefore, to stimulate his accommodation; while, under a subjective examination, the patient is looking intently at letters, trying to make them out, and this of itself many times stimulates the ciliary muscle to action. (2) The retinoscope [in the eye without atropine] shows variations in the refractive condition of the eye, perhaps indicating hypermetropia one instant and myopia the next, and where the glasses accepted by the retinoscopic test do not give uniform good vision. (3) In cases of astigmatism where the glasses accepted vary widely from the reading of the ophthalmometer, it is often an indication of spasm of accommodation.

The above are the chief symptoms of spasm of accommodation, and, as a rule, the condition is easily recognized by them, many times by means of only one or two of them. Of the subjective symptoms, the sudden change in the acuteness of vision is the most constant and reliable; and of the objective symptoms, that discovered by the ophthalmoscope is the most reliable.

How to overcome spasm of accommodation. When once satisfied that there is a spasm of accommodation, or a tendency to it, it is best to look for the cause, and try to remove that, before hastily resorting to some cycloplegic. For, even though we do use a cycloplegic and fit the patient, he is often unable to wear the glasses unless the cause of a spasm is gotten rid of. Unless, indeed, as has been recommended and practised by some ophthalmic surgeons in this country, atropin is continued for weeks after the glasses have been fitted, which seems altogether bad practice. The much better plan is to seek for and remove the cause. Failing in that, then cycloplegics are called for. In exceptional cases, no apparent cause can be discovered.

The chief causes of spasm of accommodation are: (1) conjunctivitis; (2) insufficiency of the internal recti muscles; (3) contusion; (4) sympathetic irritation, though many times contusion and sympathetic irritation are accompanied by paresis of accommodation; (5) generalized spasmodic affections; (6) overwork of the eyes; (7) hyperesthesia of the retina; (8) beginning the test for glasses with minus lenses; (9) idiopathic.

Many times, where the test for glasses at first has been unsatisfactory, and a tendency to spasm, or actual spasm, of accommodation is present, it may be best to first treat the lids for a week or ten days with a mild astringent wash. A conjunctivitis of a mild type will often cause enough irritation of the ciliary muscle to render a test for glasses unsatisfactory. Again, where the patient has been using the eyes excessively for a day or two before coming for a test, it is often necessary to make him rest the eyes, or use them easily for a day or two, before giving the final test. In hyperesthesia of the retina, shaded glasses worn for a few days before the test is made is desirable. If insufficiency of the internal recti muscles is present, a week or two of treatment with strychnia sulphate, in increasing doses, with outdoor exercise and rest, will usually suffice to relieve it, and leave the eyes in condition for testing. [See **Examination of the eye**, p. 4680, Vol. VI, as well as **Muscles, Ocular**, of this *Encyclopedia.*]

So with the other causes of spasm of accommodation when present, we try to remove them. If no apparent cause is to be found, and if the second test for the glasses is not satisfactory, and does not substantially agree with the first, we do not hesitate to use an effective cycloplegic, preferably scopolamin or atropin. See p. 43, Vol. I, and p. 3641, Vol. V of this *Encyclopedia.*

CASES ILLUSTRATING THE DIAGNOSIS AND TREATMENT OF ACCOMMODATIVE SPASM

Compound hypermetropic astigmatism with the rule; Spasm of accommodation; Amblyopia; Atropin used, and but little difference found between the glasses fitted without atropin and those fitted under it.

G. L., aged 15, in poor general health. Her eyes have troubled her since six years of age, when she entered school. She was never able to see the blackboard well, was nervous, and found it hard to sit still for any length of time. At present she has headaches, and pains in the eyes on using them for close work.

Ophthalmometer. Astigmatism with the rule, 1.50 D., axis 90° + or 180° — in each eye.

Test cards and trial lenses. The lines on the clock-dial were entirely unsatisfactory as a test.

R. V. = $\frac{10}{200}$: $\frac{20}{100}$ W. — 2 D. — 1 D. cyl., 180°.

L. V. = $\frac{10}{200}$: $\frac{20}{100}$ W. — 2 D. — 1 D. cyl., 180°.

During the test there were signs of spasm of accommodation, for first one set of lines on the clock-dial would appear plainest, then another set; and the vision at one moment would be fairly good and the next moment very poor. We therefore began to test both eyes at once, even for the astigmatism, and as the ophthalmometer showed it to be exactly the same in each eye, it was easy to do so. Placing + .25 D. cyl., 90°, before each eye, the vision was somewhat improved, and we gradually increased the strength up to + 1 D. cyl., the vision improving *pari passu.* With a stronger plus cylinder the vision was not so good as with the + 1 D. cyl., so we stopped at that point. With the cylindrical glasses in position, weak plus spherical glasses were tried before both eyes at once, with improvement in vision; and they were gradually increased up to + 1 D. sphere. Testing in this way both eyes at the same time, the patient accepted + 1 D. + 1 D. cyl., 90°, and the vision was brought up to $\frac{20}{70}$ in each eye.

Ophthalmoscope. H. 2 D. at 90° and 3.50 D. at 180° in each eye. One per cent. atropin sulphate solution was ordered; one drop in each eye three times a day for four days, and then a second test was made.

The ophthalmometer read exactly the same as at the first test.

Test cards and trial lenses.

R. V. = $\frac{20}{200}$: $\frac{20}{50}$ W. + 2 D. + 1.25 D. cyl., 90°.

$$\text{L. V.} = \frac{20}{200} : \frac{20}{50}\ \text{W.} + 1.50\ \text{D.} + 1.25\ \text{D. cyl., } 90^\circ.$$

Ophthalmoscope. H. 2 D. at 90 and 3.50 D. at 180 right eye; H. 1 D. at 90 and 2.50 D. at 180 left eye. Retinoscopy confirmed the other tests.

One week after the test under atropin, the patient was subjected to a third test. She accepted + 1.25 D. + 1.25 D. cyl., at 90° right eye, and + 1 D. + 1.25 D. cyl. at 90° left eye, and these glasses were ordered. It will be noticed that they differ but slightly from the ones that the patient accepted before atropin was used, that is, when both eyes were tested at once. In fact they differ so little that we believe she would have been almost, if not quite, as comfortable with the former as she now is with the latter, which give her entire relief from her asthenopia. Her poor vision, however, which later we found to be due to amblyopia, and the fact of her accepting minus glasses at first when the eyes were tested separately was the reason for using a cycloplegic. Under tonics and outdoor exercise her general health improved.

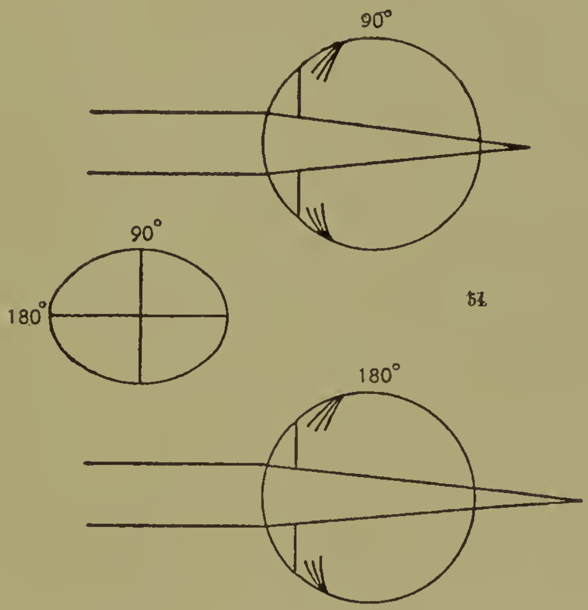

Fig. 75.

Compound hypermetropic astigmatism against the rule; Spasm of accommodation; Mild conjunctivitis; Hyperesthesia of the retina; Scopolamin used.

C. A. F., aged 22, in good general health, came for a catarrhal conjunctivitis. Two years before she had a very severe inflammation in the eyes following measles, and was confined to a darkened room for five months because of photophobia. She had glasses fitted shortly afterward, but her eyes have continued to pain her.

Ophthlmometer. No corneal astigmatism.
Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{20} \text{ W.} + .25 \text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{20} \text{ W.} + .25 \text{ D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 at 4 inches.

Ophthalmoscope. H. 1 D. in each eye; no astigmatism could be detected with the ophthalmoscope.

Although both eyes were tested at the same time, the patient would not accept any stronger glasses. Neither was retinoscopy of benefit in "fitting" this case. During the test the patient read $\frac{20}{20}$ at one moment, then her vision would blur and she could not read more than $\frac{20}{40}$. She also complained of "drawing" sensations in the eyes.

Scopolamin, one-fifth of one per cent. solution, was instilled, one drop in each eye every five minutes for six successive times; after a wait of half an hour a second test was made.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{20} \text{ W.} + 1 \text{ D.} + .25 \text{ D. cyl., } 15^\circ.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{20} \text{ W.} + 1 \text{ D.} + .25 \text{ D. cyl., } 165^\circ.$$

Ophthalmoscope. Showed the same amount of H. as at the first test.

Three days later, when the patient was no longer under the influence of the cycloplegic, a third test was made, with the following result:

$$\text{R. V.} = \frac{20}{20} : \frac{20}{20} \text{ W.} + 1 \text{ D.} + .25 \text{ D. cyl., } 15^\circ.$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{20} \text{ W.} + 1 \text{ D.} + .25 \text{ D. cyl., } 165^\circ.$$

These last glasses were prescribed, and the patient had almost immediate relief from her asthenopia, although it required weeks to relieve the photophobia; in fact, a bright light (as the glare of the sun on the water) still troubles her considerably.

Hypermetropia of large amount; Spasm of accommodation; Asthenopia; Atropin used; Relief, with 3 D. of latent hypermetropia left uncorrected.

B. K., aged 14, in good health, complains of her eyes hurting her when she tries to do close work, and of a "drawing sensation" in the eyes at times. She has always had "weak eyes" and often suffers from headaches.

Ophthalmometer. Astigmatism with the rule, .25 D., axis 105° + or 15° — right eye; .25 D., axis 75° or 165° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + .50\ \text{D.} + .25\ \text{D. cyl., } 105°.$$

$$\text{L. V.} = \frac{20}{40} : \frac{20}{20}\ \text{W.} + 1\ \text{D.} + .25\ \text{D. cyl., } 75°.$$

Reads Jaeger No. 1 from 4 to 16 inches.

Ophthalmoscope. H. 3 D. in each eye.

As the patient had signs of spasm of accommodation, first being able to read well then the vision blurring, a sense of contraction in the eyes, accepting a weak cylindrical glass and then refusing it, it was decided to use a cycloplegic, especially as the ophthalmoscope showed at least three diopters of hypermetropia. Atropin, one per cent. solution, was ordered one drop into each eye three times a day for three days.

Second test under atropin.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{15}\ \text{W.} + 5\ \text{D.}$$

$$\text{L. V.} = \frac{20}{200} : \frac{20}{15}\ \text{W.} + 5.50\ \text{D.}$$

Ophthalmoscope. 5 D. right eye; H. 6 D. left eye. At the third testing, one week later, the patient accepted + 2 D., right eye, and + 2.50 D., left eye. These glasses were ordered, and though they left about three diopters of hypermetropia in each eye uncorrected, yet they were worn with comfort and relief from asthenopic symptoms for a period of two years. This patient would not relax the accommodation when both eyes were tested at once, and even after being under atropin and coming out she yet had 3 D. of latent hypermetropia. Nevertheless, since with + 2 D. right and + 2.50 D. left the vision was $\frac{20}{15}$ and without signs of spasm of accommodation, the latent hypermetropia was left to take care of itself.

We make this distinction between the symptoms due to spasm of accommodation and latent hypermetropia. In spasm of accommodation the vision is variable, within short periods of time, and often with sensations of "drawing" in the eyes, and the ophthalmoscopic and retinoscopic examinations show the refraction to vary. In latent hypermetropia the ciliary muscle is able to and does correct steadily and without irregular action that portion of the total hypermetropia which is latent. As long as the ciliary muscle can do this with comfort and without strain, the latent hypermetropia remains practically the same, at least does not vary suddenly, and the subjective examinations do not discover it, unless, when for some special reason, we use a cycloplegic. As the patient grows older, however, or becomes ill or overworked, the ciliary muscle may not be able to keep up its steady and comfortabde action, and begins to manifest signs of fatigue and to act irregularly, to exhibit variable vision, a sense of drawing the eyes, headache, etc. It is at this time that aid to the ciliary muscle is called for and should be given, but as long as the ocular apparatus can do its work with comfort, and without bother to the patient, it is better not to interfere.

We shall give here also a single case of spasm of accommodation occurring in simple hypermetropic astigmatism; later some cases of spasm of accommodation occurring in myopia, myopic astigmatism, and mixed astigmatism.

Simple hypermetropic astigmatism; Spasm of accommodation; Marked asthenopia; Minus cylindrical glasses accepted without atropin and perfect vision obtained; Plus cylindrical glasses accepted under atropin and perfect vision.

H. T., aged 19, in good health, has been troubled with her eyes for the last four years; in fact, more or less ever since she entered school. She cannot read or sew for any length of time without pain in the eyes, and if she persists in her work has headaches. Some slight injection of the conjunctiva.

Ophthalmometer. Astigmatism with the rule, 1.25 D., axis 90° + or 180° — in each eye.

Test cards and trial lenses. The vertical lines on the clock-dial appear plainest.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{15} \text{ — W. — .75 D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{15} \text{ — W. — .75 D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 from 6 to 15 inches.

Ophthalmoscope. Emmetropia vertical meridian (90°) and H. .50 D. in horizontal meridian (180°) in each eye.

Although both eyes were tested at once, the patient would accept only minus glasses. Retinoscopy [in the eye free of atropia] gave myopic astigmatism. A wash was prescribed for the mild conjunctivitis, the patient ordered not to use the eyes so hard, and to report in a week. A second test was given, with exactly the same result as on the first visit. Signs of spasm of accommodation were present. Atropin, solution 4 gr. to ℥1, was ordered instilled, one drop three times a day for three days.

Test under atropin: Ophthalmometer read the same as on the two previous tests.

Test cards and trial lenses. Horizontal lines on the clock-dial are seen plainest now.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{15} \text{ — W.} + .75 \text{ D. cyl., } 90^\circ.$$

$$\text{L. V.} = \frac{20}{50} : \frac{20}{15} \text{ — W.} + .75 \text{ D. cyl., } 90^\circ.$$

A week later, when the effect of atropin had passed off, the patient again accepted + .75 D. cylindrical glass, axis 90, in each eye,

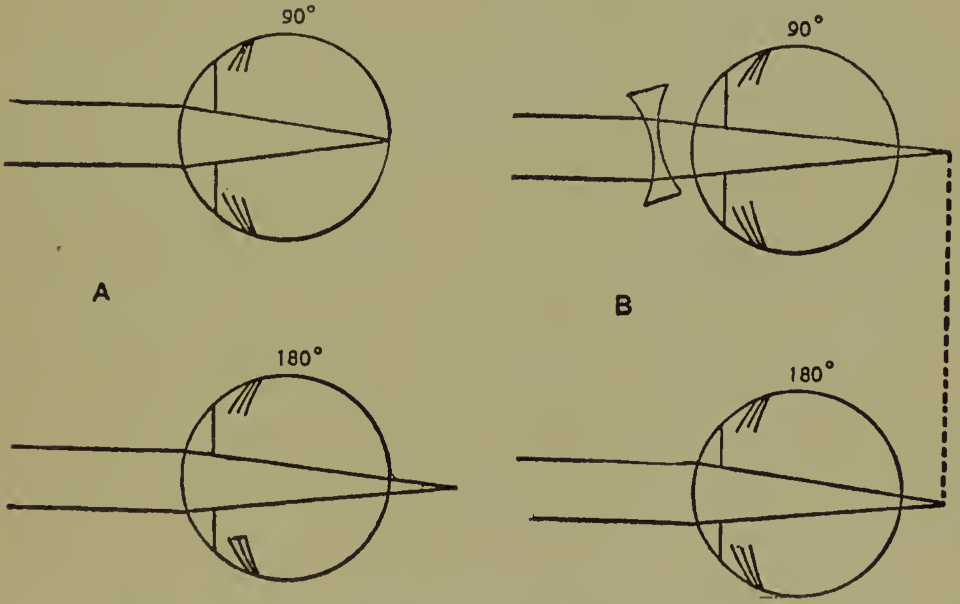

Fig. 76. Showing how a simple Minus Cylindrical Glass can Convert a Simple Hypermetropic Astigmatism into Simple Hypermetropia.

and they were ordered. These glasses were worn for more than four years, and with relief from the asthenopic symptoms.

In some cases of simple hypermetropic astigmatism a patient will accept a minus cylindrical glass and get relief from all asthenopic symptoms. This is to be explained by the fact that the patient converts the simple hypermetropic astigmatism into a simple hypermetropia (see Fig. 76). By so doing, the ciliary muscle can act in its entire circumference and correct the simple hypermetropia of small amount with ease and without fatigue; whereas it could not correct an equal amount of hypermetropic astigmatism, because it would be compelled to contract irregularly, and in that way cause asthenopia or painful vision.

Anterior lenticular astigmatism with the rule, each eye. Has a feeling as if something were in front of the eyes. Headaches.

E. H., aged 29. Wearing:
R. E. 2.50 cyl., 105°.
L. E. 2.50 cyl., 75°.

Ophthalmometer: Astigmatism with the rule, 1.50 D., axis 105° + or 15° —, right eye.

Astigmatism with the rule, 1.50 D., axis 75° + or 165° —, left eye.

Test cards and trial lenses.

R. V. $= \frac{20}{50} : \frac{20}{20}$ W. + 1.50 D. = + 1.50 cyl., 105°.

L. V. $= \frac{20}{50} : \frac{20}{20}$ W. + 1.50 D. = + 1.50 cyl., 75°.

Reads Jaeger No. 1 from 7 to 8 inches.

Ad. 10°, ab. 6°, sur. R. & L. 2°.

Ophthalmoscope: H. 1.50 D. at 105°, and H. 2.50 D. at 15°, right eye.

H. 1.50 D. at 75°, and H. 3 D. at 165°, left eye.

Two days later, ophthalmometer: same.

Test cards and trial lenses.

R. V. $= \frac{20}{50} : \frac{20}{20}$ W. + 1.37 = + 1.62 cyl., 105°.

L. V. $= \frac{20}{50} : \frac{20}{20}$ W. + 1.25 = + 1.75 cyl., 75°.

Three years later, troubled with headaches. Homatropin cycloplegia.

Ophthalmometer: (Corneal). Astigmatism with the rule: 1.50 D., 105° + or 15 —.
(Lenticular). Astigmatism against the rule: .25 D., 15° + or 105 —.
Right eye

(Corneal). Astigmatism with the rule: 1.50 D., 70° + or 160° —.
(Lenticular). Astigmatism against the rule: .25 D., 160° + or 70° —.
Left eye

R. V. $= \frac{20}{70} : \frac{20}{20}$ W. + 2 D. = + 1.62 cyl., 105°.

L. V. $= \frac{20}{70} : \frac{20}{20}$ W. + 175 D. = + 1.75 cyl., 70°.

The retinoscope and ophthalmoscope confirmed the subjective tests. Measurement of the anterior surface of the lenses was difficult, though apparently there was a small amount of astigmatism with the rule. The glasses that the patient accepted indicate the same. Since there was a corneal astigmatism of only 1.50 D. with the rule in each, a posterior lenticular astigmatism of .25 D. subtracted from the corneal would leave 1.25 of astigmatism with the rule to be corrected. The patient, however, accepted 1.62 D. cyl., right eye, and 1.75 D. cyl., left eye, axes *with the rule.* This result most likely is due to an anterior lenticular astigmatism with the rule in each eye, 37 D. right, and .50 D. left.

CHAPTER XI.

MYOPIA. SIMPLE MYOPIC ASTIGMATISM. SPASMODIC OR FALSE MYOPIA. RULES FOR PRESCRIBING NEAR OR READING GLASSES IN HIGH DEGREES OF MYOPIA. PRESBYOPIA AND THE TRANSPOSITION OF GLASSES FROM DISTANCE TO READING FORMULÆ IN MYOPES. ILLUSTRATIVE CASES.

The tests for glasses in myopia and myopic astigmatism are begun in the same routine manner as in other cases, that is, first use the ophthalmometer, followed by the subjective test with test lenses; then the ophthalmoscope and the retinoscope. Furthermore, begin the test with plus glasses just as we do in all cases, because, not knowing the nature of the error of refraction, it is safe to begin only with plus glasses. Should the patient prove to be hypermetropic, and minus glasses are tried first, they often incite a spasm of accommodation and are accepted when they should not be; while, if plus glasses are first tried we can be sure they will not be accepted by a myope, and we can find this out by the trial of only two or three glasses and without the risk of inciting spasm of accommodation. Of course, if the ophthalmoscope is used before glasses are tried it indicates the kind of glass to be tried first. As a rule, however, we prefer not to make an ophtahlmoscopic examination until we have used the test cards and trial case, because if light is thrown into the eyes for any considerable time just before testing the vision, it often impairs the value of the test.

Before giving illustrative cases it may be well to draw a clear distinction between true or axial myopia and false or spasmodic myopia. *True myopia* is present when, to repeat, the axis of the eye is too long, allowing the rays of light to focus in front of the retina (see Fig. 77). Myopia may be small or large in amount, according to the increase of length of the eyeball beyond that of the emmetropic eye, which latter is about 23 mm. When the eye becomes elongated rapidly, attended with changes in the choroid and sclera, with posterior staphyloma, etc., it is called progressive or *malignant* myopia.

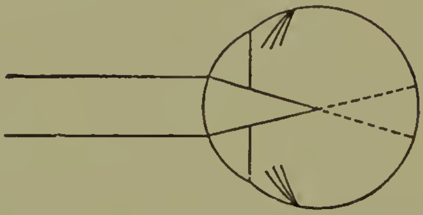

Fig. 77. True or Axial Myopia, Parallel Rays Focusing in Front of the Retina, Crossing and Forming Diffusion Circles on the Retina.

False myopia is nothing more than a spasm of the ciliary or focusing muscle. To illustrate, say the patient is emmetropic, but for some reason the ciliary muscle is overacting. By so doing the eye is rendered myopic by the lens becoming thicker, causing the rays to focus in front of the retina. Furthermore, this patient would accept minus glasses with improvement of vision, as long as this form of spasm of accommodation lasted.

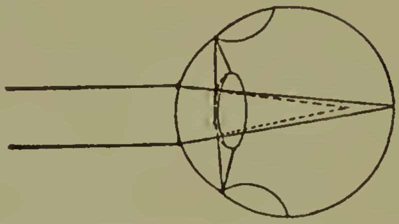

Fig. 78. False Myopia in an Emmetropic Eye, Due to Spasm of Accommodation. Dotted line shows false focus.

False myopia may be present even in hypermetropia, the focus being moved from back of the retina to the front of it by spasm of the accommodation. Again, false myopia may be present in the same eye with true myopia, that is, the spasm of accommodation increases the amount of the true myopia.

It is altogether important to recognize the difference between true and false myopia; for while true myopia should be carefully corrected, false myopia should never have a glass prescribed for it, but its cause should be looked for and remedied, if possible, upon which it disappears and requires no further treatment.

Of *curvature* myopia it is hardly worth while to speak, more than to say that such a thing exists. It is due to excessive curvature of the cornea, and not to lengthening of the eyeball (see Fig. 79).

It is a rare error of refraction, and when present it is usually due to some pathological condition, conical cornea, staphyloma of the cornea, etc., for which conditions glasses are of but little benefit.

Curvature myopia may also result from excessive curvature of the lens surfaces—lenticonus, posterior or anterior. [See, also, the various **Myopia** rubrics, pp. 8265-8275, in this *Encyclopedia.*]

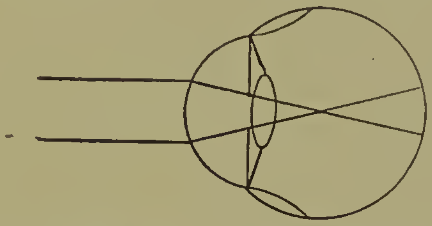

Fig. 79. Curvature Myopia, Where the Length of the Eyeball is Normal, but the Cornea is too much Curved.

ILLUSTRATIVE CASES OF MYOPIA.

Simple myopia of high degree, greater in the right eye; Patient uses one eye for the distance and the other for near.

Mrs. A. S., aged 50; has worn glasses since 16 years of age. Imperfect sight and pains in right side of head at times.

Ophthalmometer: negative.

Test cards and trial lenses.

$$\text{R V.} = \frac{5}{200} : \frac{20}{30} \text{ W.} - 11 \text{ D.}$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{30} \text{ W.} - 8 \text{ D.}$$

Reads Jaeger No. 1 from 8 to 11 inches, — 7 D., right
— 5 D., left.

Has a crossed horizontal diplopia with red glass. Patient is now using — 8 D. sphere in each eye, and uses the right eye to read with and the left eye to see in the distance. Has not single, binocular vision. Of late she has some trouble in threading needles.

Ophthalmoscope shows M. 11 D., right, marked choroidal *tigre* and a small crescent at the temporal side of the disc; otherwise the fundus is in good condition. Left, M. 8 D., choroidal *tigre.*

Retinoscope: shows M. 11 D., right eye, and M. 8 D. left eye.

Ordered, — 6 D., right, and the left glass to remain as it is for the distance. The patient is not troubled with diplopia and the new glasses are worn with comfort.

Simple myopic astigmatism with the rule; Blepharitis marginalis; Slight asthenopia.

C. G., aged 29, in good health, always had poor vision, and for the last four years his eyelids get red at the edges when he used his eyes for close work of any kind. There is but little pain in the eyes, but the lids itch and burn. He has no headaches.

Ophthalmometer. Astigmatism with the rule, 3 D., axis 90° + or 180° — in each eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{15}\ \text{W.} - 2.50\ \text{D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{50} : \frac{20}{15}\ \text{W.} - 2.50\ \text{D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 at 12 inches.

Ophthalmoscope. Myopia 3 D. at 90° and emmetropia at 180° in each eye.

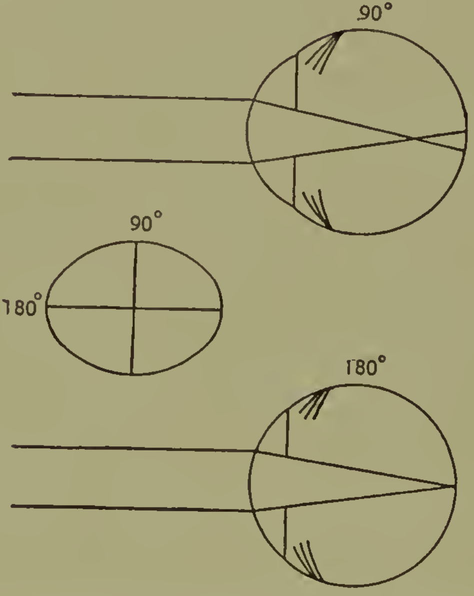

Fig. 80. Showing Myopia of 3 D. in the Vertical Meridian, and Emmetropia in the Horizontal Meridian.

A wash of boric acid solution was ordered twice a day, and an ointment of yellow oxide of mercury, eight grains to one ounce of vaseline, to rub on the eyelids at night. Two weeks later the lids were very much improved in appearance. A second test for glasses was made, and the patient accepted exactly the same glasses as at the first test. Ordered — 2.50 D. cyl., 180°, for each eye, which have been worn with an entire relief from the lid trouble.

In this case the test was begun with plus cylindrical glasses, just as we do in all cases where the ophthalmometer indicates astigmatism, but, as the vision was made worse, minus cylindrical glasses were immediately tried with improvement in the vision. Their strength was gradually increased up to — 2.50 D., when vision was brought up to $\frac{20}{15}$. No minus spherical glasses were tried in addition to the cylindrical glasses in this case, for the $\frac{20}{15}$ vision, obtained by the patient with simple cylindrical glasses was proof that no myopia was present in addition to the astigmatism.

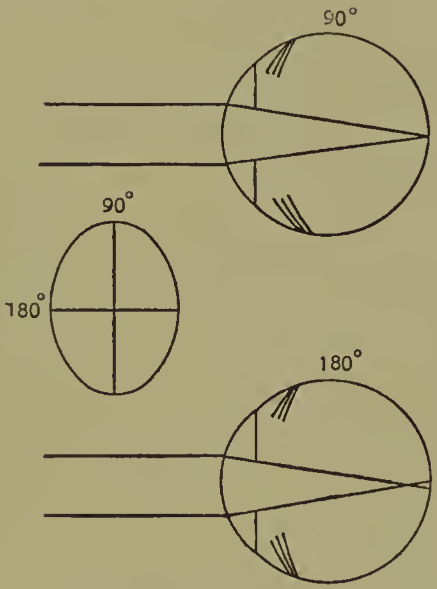

Fig. 81. Showing Myopic Astigmatism Against the Rule—Emmetropia in the vertical meridian and Myopia in the horizontal meridian.

No corneal astigmatism; Patient accepts .50 D. cylindrical glasses against the rule; Relief from asthenopia.

J. A., aged 23, in excellent health, has been troubled with his eyes for the last two years. After using the microscope or ophthalmoscope he has pains in the eyes, and if he persists headaches follow.

Ophthalmometer. No corneal astigmatism whatever.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} - .50\ \text{D. cyl., } 90^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} - .50\ \text{D. cyl., } 90^\circ.$$

Reads Jaeger No. 1 from 4 to 20 inches.

Ophthalmoscope. Myopia .50 D. at 180° and emmetropia at 90° in each eye.

A second test resulted in the patient accepting exactly the same glasses as at the first test, and they were ordered, with complete relief of his asthenopia.

The retinoscope was used in this case to advantage, as it indicated myopia of a small amount in the horizontal meridian. The lines on the clock-dial were of service also, as they indicated either hypermetropic astigmatism with the rule, or myopic astigmatism against the rule. Keeping in mind also the fact that, most of the time, when there is no corneal astigmatism, there is often a small amount of lenticular astigmatism against the rule, we began the test with a plus cylindrical glass, with the axis at 180°. But this glass made vision worse, so we tried minus cylindrical glasses at 90°. They improved vision, the patient accepting — .50 D. cyl., 90°, and getting the best vision.

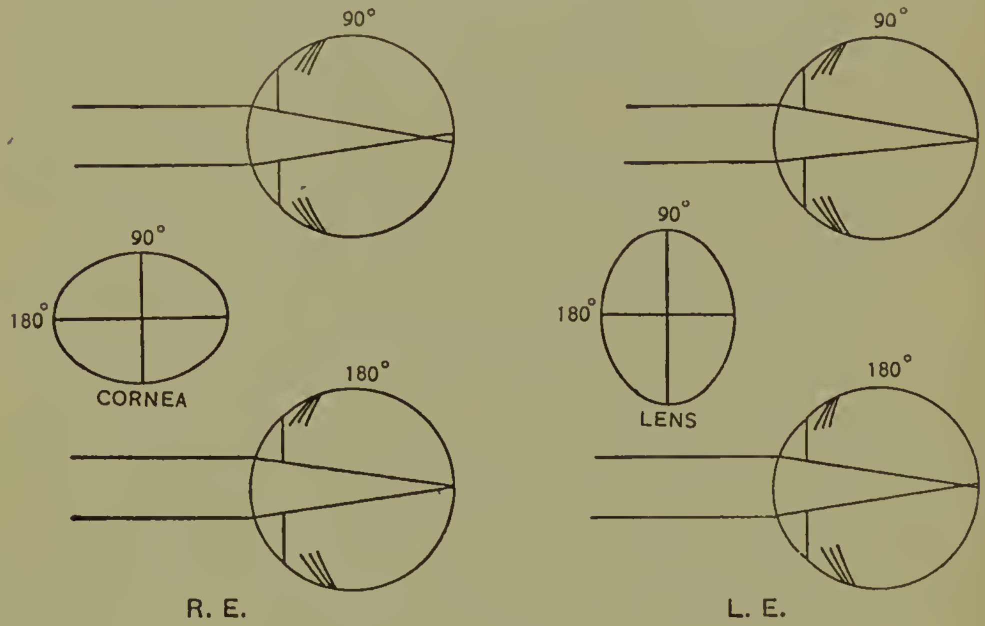

Fig. 82.

Simple myopic astigmatism with the rule in the right eye; Lenticular astigmatism against the rule in the left eye, the ophthalmometer showing no corneal astigmatism; Asthenopia; Relief with glasses.

M. L. H., aged 25, in good health, is a designer of wall papers, requiring very acute vision. The patient complains that for the last two months her eyes have ached and pained, and also that her head ached if she persisted in using her eyes for an hour or two at her work.

Ophthalmometer. Astigmatism with the rule, 1 D., axis 90° + or 180° — right eye; No corneal astigmatism left eye.

Test cards and trial lenses. The test with the lines on the clock-dial were unsatisfactory.

$$\text{R. V.} = \frac{20}{40} : \frac{20}{20} \text{ W. — 75 D. cyl., 180°.}$$

$$\text{L. V.} = \frac{20}{40} : \frac{20}{20} \text{ W. } - 50 \text{ D. cyl., } 90^\circ.$$

Reads Jaeger No. 1 from 6 to 12 inches.

Ophthalmoscope. Myopia 1 D. at 90° and emmetropia at 180° right eye; myopia .75 D. at 180° and emmetropia at 90° left eye.

The retionscope confirmed the ophthalmoscopic examination and the subjective test.

A second test was made, and as the patient accepted the same glasses as at first, they were ordered. Although one glass is worn at 90° and the other at 180°, they have given her entire relief from her asthenopic symptoms.

Corneal astigmatism with the rule, .50 D.; Patient accepts simple spherical glasses of high power for distance; Weaker for reading. The rule for giving two pairs of glasses in high degrees of myopia considered.

I. G., aged 32, in good health, has had poor vision as long as he can remember. No pain in the eyes or headaches are complained of — simply poor sight.

Ophthalmometer. Astigmatism with the rule, .50 D., axis 90° + or 180° — in each eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{4}{200} : \frac{20}{50} \text{ W. } - 14 \text{ D.}$$

$$\text{L. V.} = \frac{12}{200} : \frac{20}{30} \text{ W. } - 11 \text{ D.}$$

Reads Jaeger No. 1 at 8 inches, with — 11 D. right eye, and — 8 D. left eye.

Ophthalmoscope. Myopia 15 D. right eye, myopia 12 D. left eye. Excessive pigmentation of choroid in each eye, but no staphyloma in either. Vitreous clear in both.

On a second test, the patient accepted the same glasses, both for the distance, and the near-point, as at the first test, and they were ordered.

The corneal astigmatism of half a diopter in this case was neutralized by the lenticular astigmatism, the usual amount of neutralization, which left a simple myopia to deal with. The myopia was so great, however, that two pairs of glasses had to be prescribed—one for distance and the other for reading; and not, as will be noted, on account of presbyopia, for the patient was but thirty-two years of age. The rules for procedure in these cases are briefly as follows:

Rules for ordering glasses in high myopia.

If the myopia is of 8 D. or less, as a rule, the patient will need but one pair of glasses, which can be used both for the distance and the near-point. If the patient has worn glasses from early childhood, this one pair is usually sufficient; for, having worn glasses steadily, and thereby kept the eye corrected both for far and near work, the ciliary muscle has been developed. On the other hand, patients who have not used glasses till later in life (fifteen to twenty years of age), or have worn only a partial correction (say, for myopia of 12 D. only 8 D. for the distance, and no correction for the near-point) will not tolerate the distance glass for constant wear. This is because the ciliary muscle has not been developed, the patient taking off his glasses and bringing his work close to him at the focus, *punctum remotum,* of his myopic eye. In this way no accommodative effort is necessary, the ciliary muscle remains passive, has no exercise and the muscle fibres do not develop. In such cases, the reading glasses have to be made weaker, just as in the higher grades of myopia.

In high degrees of myopia, 8 D. or over, a good rule of procedure is to find the glasses which give the best distant vision, as in other cases; if the glasses accepted are not higher than 10 or 12 D., and there are no pathological changes in the fundus of the eye of a serious nature, especially if the patient has been wearing nearly his full correction before, prescribe these glasses for distant vision. In myopia of higher degree than this, the patient will not accept his full correction even for the distance, except for very brief periods at a time. In such cases the full correction may be prescribed to be used in a lorgnon, or which is more often done, the glass in the lorgnon is of sufficient strength when held in front of the glasses worn constantly to give full correction. The amount of reduction depends on the strength of the glasses the patient has previously worn, the age of the patient, and the condition of the fundus of the eyes.

Roughly speaking, we would say that a myope of 14 D. should wear about 12 D. as a constant distance glass; a myope of 16 D. a 13 D.; a myope of 18 D. a 15 D.; and a myope of 20 D. a 16 D. glass, and so on. But there are numerous exceptions. It is rare to encounter myopia of over 25 D., though cases of as high as 40 D. have been reported and that without conical cornea.

To *estimate the correct reading glasses in high degrees of myopia,* after having found the glasses wanted for the distance, divide the number of inches at which the patient wishes to read, or sew, or work, into 40, in order to reduce it to diopters, then subtract the quotient from the distance glasses.* The result is the number of the glass in diopters the patient will usually accept for his close work; but a still further reduction may have to be made in their strength if the patient has not worn glasses for a long time, or if the myopia is of very high amount.

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* Forty is the number of English inches it takes to make a meter, and if the trial lenses are ground after the English inch (also numbered in diopters), reckon in that system.

All trial cases were formerly marked in the inch system. For example, a glass of 10-inch focus would be marked 1/10, one of 40-inch focus, 1/40, etc. But as confusion was caused by the difference in length of the English and French inches, the dioptric or metric system of numbering was introduced.

In the dioptric system of numbering, the meter is taken as the unit of measure. For example, a glass that will focus parallel rays of light at a distance of one meter is marked one diopter (1 D.); a glass that focuses the same rays at half a meter would have to be twice as strong, and is marked 2D. A glass that focuses rays at two meters' distance would be marked .50 D., or half a diopter. The numbering goes on in an inverse ratio, for the shorter the focus the stronger the glass, necessarily. The metric or dioptric system of numbering is much better than the inch system, for a meter is a meter the world over, while inches of different peoples vary.

It should be borne in mind at all times in fitting glasses, that all eyes are not alike in their working capacity, and will not conform, in exactly the same way, to any set standard or rule. This does not mean that we should not have a working rule at all, but that we should have enough intelligence to vary the rule to *suit the case,* and not try to make every case *fit some cast-iron rule.*

In some cases, *for the near point,* we may have to subtract more from the distance glasses than just indicated; in some cases less. The power of convergence has something to do with this modification of the rule; so may have the strength of the glasses the patient has previously worn, as well as the age of the patient; all these have to be taken into consideration when prescribing reading glasses for a myope. Indeed, Landolt (*Refraction and Accommodation of the Eye,* p. 490) has laid down, as a general rule applicable to all degrees of myopia, that "A myope must be prohibited from wearing a concave glass for any distance at which he can see clearly without accommodation." For example, a young myope of 2 D. should not have any glass at all for distances under 20 inches, because his *punctum remotum* is at 20 inches, and he can see clearly without them up to that point. It is a good plan, however, in all myopes under 8 D., who are compelled to wear glasses for the distance, to keep their glasses on all the time, unless troublesome asthenopia results; then the distance glasses should be weakened for the near-point according to the rule laid down above. The reason for wearing the distance glasses for near work in such cases is, first, to exercise and develop the ciliary muscle; second, to render the eye emmetropic for all distances, and thus keep up the proper relation between accommodation and convergence; third, because it is less trouble to keep the glasses on all the time than to be taking them off and putting them on frequently. Of course, in very high degrees of myopia, two pairs of glasses have to be resorted to, and sometimes three, if we include the lorgnon which patients sometimes use for only a few moments. In cases of high degree of myopia it is, in fact, never a question of glasses alone, especially where progressive or malignant myopia is to be dealt with. In such cases a hygienic program should be followed so far as the eyes are concerned, and the constitution built up with tonics and other remedies. All close work with the eyes must be prohibited, shaded glasses worn, the patient made to exercise outdoors and to take proper amount of rest; and so forth. Unfortunately, these forms of myopia often develop in childhood, when the patient is trying to pursue his studies. It is unnecessary to say that such patients must be taken out of school, because close application to books always makes the myopia worse.

In high degrees of myopia, not malignant in character, that is, cases with healthy fundi, or, at most, with only a slight posterior staphyloma, and with but little tendency to increase, it is well for the patient to use the eyes as little as possible, and then only with good light. In order to prevent straining the eyes, these patients often acquire the practice of using but one eye at a time, especially for near work, taking off the glasses and bringing the print up to the focus (*punctum remotum*) of the eye they use. In this way they use no accommodation, and, at the same time, the images appear much larger than with the strong concave glasses. The eye that is not used usually swings out, that is, diverges.

Where the eyes are sound, always encourage the use of glasses, as they give a stimulus to binocular vision both for the distance and for the near-point. A divergent squint is sometimes prevented in this way, just as in hypermetropia, a convergent squint is sometimes prevented and even cured in young children by wearing plus glasses.

The following case of moderate degree of myopia in one eye, and only a small amount in the other, with a tendency to, and, at times actual, squint outward, is an illustration in point.

Myopia of moderate amount in one eye and small amount in the other; Occasional divergent squint; Asthenopia; Relief of the squint and asthenopia with correcting glasses.

E. M. L., aged 21, in good health, has been near-sighted in the right eye since childhood; her family noticed at times, when she was looking in the distance, that the right eye turned outward. With close attention, however, there was no squint. When she reads at night the eyes tire, but there is little pain in them, and she rarely has headaches.

The ophthalmometer showed a small amount of corneal astigmatism in each eye; and, on the first test, the patient accepted compound glasses, but, on the second test, simple concave spherical glasses gave the best vision.

Ophthalmometer. Astigmatism with the rule, .75 D., axis 75° + or 165° — right eye; .25 D., 90° + or 180° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{20} - \text{W.} - 4.50\text{ D.} - .50\text{ D. cyl., } 165^\circ.$$

$$\text{L. V.} = \frac{20}{20} : - : \frac{20}{20}\ \text{W.} - .25\text{ D.} - .25\text{ D. cyl., } 180^\circ.$$

Reads Jaeger No. 1, 3 to 12 inches right eye, and from 5 to 15 inches in the left eye. Unless she looks at the point attentively, the right eye turns outward for the near-point; also, when looking in the distance, unless she is attentive, the right eye swings outward.

Ophthalmoscope. Myopia 5 D. right eye; myopia 1 D. (?) left eye; normal fundi.

A mild conjunctivitis was treated and a second test made. This latter seemed advisable, because there were unmistakable signs of spasm of accommodation during the subjective test. The retinoscopic test was unsatisfactory.

Second test: the ophthalmometer gave the same reading as at the first test.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{20} \text{ W.} - 5 \text{ D.}$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{20} + \text{W.} - .50 \text{ D.}$$

The ophthalmoscope and retinoscope both confirmed the subjective test. The tendency to spasm of accommodation had subsided. We ordered for constant wear — 4.50 D. right, and a plane glass left. The patient has been under observation for a period of eight months. She has single binocular vision both for near and far with the glasses and is entirely free from asthenopia.

Myopic astigmatism of moderate amount; Presbyopia; Simple minus cylindrical glasses for the distance, and cross-cylindrical glasses for reading.

J. L., aged 45, in good health, has worn glasses since nineteen years of age, which are all right for the street now, but have not been comfortable for reading purposes for the last two or three years. Her distance glasses are — 2 D. cyl., 180°, in each eye.

Ophthalmometer. Astigmatism with the rule, 2.50 D., axis 90° + 180° — in each eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{20} \text{ W.} - 2 \text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{20} \text{ W.} - 2 \text{ D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 from 7 to 18 inches, with + 1 D. spherical glass added to the distance glasses.

Ophthalmoscope. M. 2 D. in the vertical meridian, and emmetropia in the horizontal meridian in each eye.

The patient was allowed to wear the minus cylindrical glasses for distance and + 1 D. — 2 D. cyl., 180°, was ordered for each eye for reading. These glasses are the same as cross-cylinders, that is, + 1 D. cyl., 90° — 1 D. cyl., 180°.

It is, as a rule, an easy matter to estimate the correct reading glasses for an emmetrope or for a hypermetrope but in myopic astigmatism, for example, the fitting of glasses for presbyopes is not so easy, especially for the beginner; since the change from minus cylindrical glasses to plus, with change of axis, though apparently simple as an algebraic equation, is not, as a rule, quickly grasped by the student. For this reason, diagrams are valuable, showing the focus of the two chief meridians for the distance, and then the change of focus brought about by presbyopia. This places before the eye of the student the change of focus of each meridian, and at the same time indicates the nature and strength of the glass necessary for the near work of the patient. It has the further advantage of making the student think of the eye under observation, and does not let him decide the matter by an abstract algebraic equation. This may seem of little importance to those who do not instruct; but, to teachers, this method of imparting knowledge will at once be apparent as the better method of teaching.

In simple myopia without astigmatism, the fitting of glasses in presbyopic patients is not difficult, because, by adding + 1 D. for each five years of age after forty to the distance glass, we easily obtain the (theoretically) correct glass for reading or working. For example, the patient wears — 2 D. for distant vision, and is forty-five years of age. Add + 1 D. to — 2 D., and we have left — 1 D., which would be the reading glass. At fifty years of age the patient would be 2 D. presbyopic. Plus 2 D. added to — 2 D. equals 0, that is, they exactly neutralize, so that the patient would need no reading glasses at this age. At fifty-five years of age + 3 D. added to — 2 D. would give + 1 D., which would be the correct glass for reading.

In cases of *simple myopia of high degree,* where two pairs of glasses are worn, in giving presbyopic glasses, we add the dioptric value of the presbyopic glass to that of his weaker glasses (those he uses for near work), and leave the distance glasses as they were. Nevertheless, even the distance glasses of high myopes must be weakened as the patient advances in age; because the static refraction of the eye begins to get "weaker" at fifty years of age; and at eighty years has actually decreased about 2.50 D. In one of the illustrative cases for instance, where — 14 D., right, and — 11 D., left, were ordered for the distance; and — 11 D., right, and — 8 D., left, for reading—when this patient reaches forty-five years of age he should wear, on account of his 1 D. of presbyopia, + 1 D. added to the — 11 D. right, and + 1 D. added to — 8 D. left, which gives for reading — 10 D., right, and — 7 D., left. At fifty years of age + 2 D. added to — 11 D. and — 8 D. would give — 9 D. and — 6 D., respectively, as the reading glasses; and so on.

On account of the decrease of the static refraction of the eye, this patient's strong distance glasses should be decreased in strength, and much more than is indicated by the tables of scales given in the various text-books. At the age of sixty, for instance, the static refraction has decreased .50 D., yet a much greater reduction in the strength of the distance glasses will, in practice, have to be made than this amount where the myopia is of high degree.

In *myopic astigmatism with presbyopia* we have to deal with the transposition of cylindrical glasses, which is not so easy as in simple myopia with spherical glasses.

Let us assume the patient to be forty-five years of age and to have accepted for the distance — 1 D. cylindrical glass, axis 180°, in each eye. He now requires a reading glass and should accept + 1 D. cyl., 90°, in each eye. A + 1 D. spherical glass added to

— 1 D. cyl., 180°, would be in effect + 1 D. cyl., 90°. As the former glass is simpler, lighter, and cheaper, it was prescribed. A glance at Fig. 83 will show the change in focus brought about by the 1 D. of presbyopia.

The 1 D. of myopia in the vertical meridian is just neutralized by the 1 D. of presbyopia; while the horizontal meridian, which is emmetropic becomes in effect hypermetropic 1 D., by reason of the 1 D. of presbyopia. In other words, the eye for reading purposes at that age is converted into a simple hypermetropic astigmatic eye, and requires a simple + 1 D. cyl., 90°, to correct it.

At fifty years of age the patient would require as a reading glass + 1 D.s + 1 D. cyl., 90; for, on account of 2 D. of presbyopia, the focus in the vertical meridian, for reading purposes, has receded behind the retina, as well as the focus in the horizontal meridian (in the vertical meridian 1 D. and in the horzontal meridian 2 D.). A + 1 D. sphere corrects the vertical meridian and half the presbyopia of the horizontal meridian, the + 1 D. cyl., 90°, being required to complete the correction in the horizontal meridian.

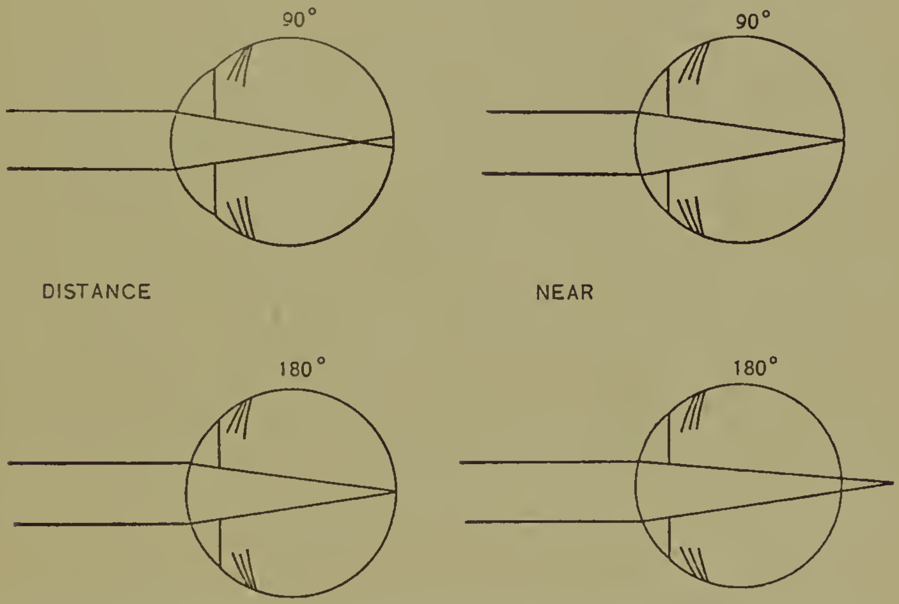

Fig. 83. Showing Focuses of Chief Meridians for Distant Vision and for Near Vision at the age of forty-five years, in simple myopic astigmatism of 1 D.

At fifty-five years of age, this patient would require + 2 D.s + 1 D. cyl., 90°, and so on, about + 1 D. spherical glass extra for each five years being required to be added to the cylindrical glass.

Take another example. Suppose the patient accepts — 2 D. cyl., axis 180°, for the distance. At forty-five years of age, this patient would be about 1 D. presbyopic, and should wear for reading + 1 D. — 2 D. cyl., 180°, in each eye; or, if we chose, we could give cross-cylinders, e. g., + 1 D. cyl., 90 — 1 D. cyl., 180°, which is exactly the same in effect as the sphero-cylindrical glass + 1 D. — 2 D. cyl., 180°.

To make this perfectly plain, we will give a diagram of the eye, showing, first, the foci of the two chief meridians for distance vision; and, second, the foci as affected by the 1 D. of presbyopia at forty-five years of age.

The 1 D. of presbyopia neutralizes 1 D. of the myopic astigmatism in the vertical meridian (leaving 1 D. of it uncorrected), and at the same time renders the horizontal meridian (which is emmetropic) presbyopic, or in effect hypermetropic 1 D. Thus the eye for reading purposes exhibits a mixed astigmatism, since it focuses rays of light in front of the retina in the vertical meridian, and back of the retina in the horizontal meridian. To correct this we can give either the cross-cylindrical glasses + 1 D. cyl., 90° — 1 D. cyl., 180°; or we can prescribe sphero-cylindrical glasses, + 1 D. — 2 D. cyl., 180°. In the first instance, with the cross-cylinders, the + 1 D. cyl., 90°, corrects the 1 D. of presbyopia in the horizontal meridian, and the — 1 D. cyl., 180°, corrects the one remaining diopter of myopic astigmatism in the vertical meridian. In the second instance, with the sphero-cylindrical glasses, the + 1 D. sphere corrects the 1 D. of presbyopia in the horizontal meridian, and at the same time renders the eye myopic to that extent in the vertical meridian; and the increase of myopic astigmatism by 1 D. in addition to the 1 D. already present makes it necessary to give — 2 D. cyl., 180°, instead of — 1 D. cyl., as when cross-cylinders were prescribed. In other words, we have to neutralize the effect of the plus spherical glass in the vertical meridian. This, of course, makes a heavier glass than a cross-cylinder. The field of vision also is made somewhat smaller by the sphero-cylindrical glasses than by the cross-cylindrical; but both these objections are of but little importance in mixed astigmatism of low degree, as in the present instance.

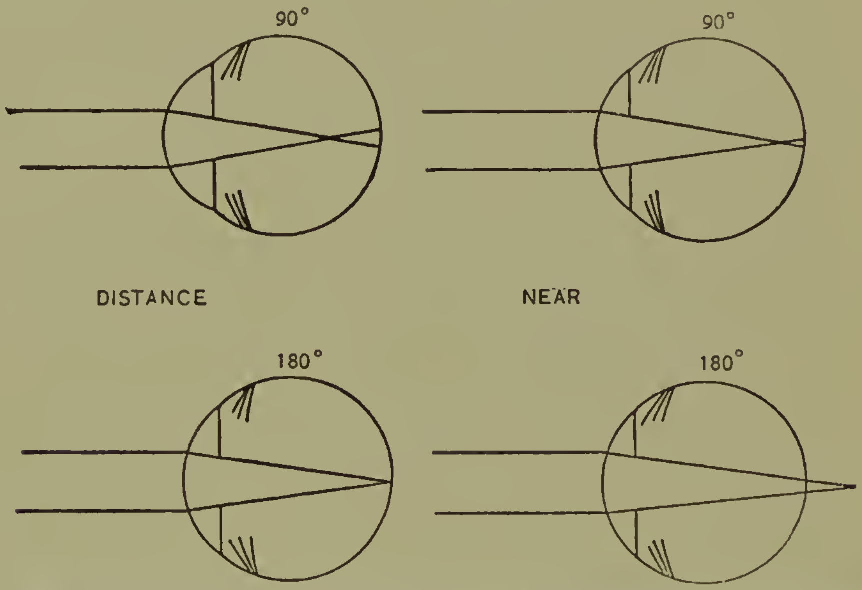

Fig. 84. Showing Focuses of the Chief Meridians in Simple Myopic Astigmatism of 2 D. for distant vision and for near vision at the age of forty-five years.

When the mixed astigmatism is of large amount, cross-cylindrical glasses are, as a general rule, to be given in preference to sphero-cylindrical.

At fifty years of age, the patient just referred to would require a simple + 2 cyl., axis 90°, because at this age the 2 D. of myopic astigmatism in the vertical meridian is just neutralized by the 2 D. of presbyopia, while the emmetropic horizontal meridian is rendered 2 D. presbyopic (or hypermetropic in effect), and requires the + 2 D. cyl., 90°, to correct same. At fifty-five years of age, the patient would wear + 1 D. + 2 D. cyl., 90°; and at sixty years, + 2 D. + 2 D. cyl., 90°, and so on.

For the transposition of glasses made necessary on account of presbyopia in compound myopic astigmatism and in mixed astigmatism, suitable examples are given for illustration in the following section.

Simple myopic astigmatism with the rule; Presbyopia; Minus cylindrical glasses for the distance, and plus cylindrical glasses for near work.

S. T., aged 46, in good health, has worn glasses since twenty years of age, on account of near-sightedness. For the past two years he has experienced some trouble in near work, especially when reading at night.

Ophthalmometer. Astigmatism with the rule, 1.50 D., axis 90° + or — 180° in each eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{15}\ \text{W.} - 1\ \text{D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{15}\ \text{W.} - 1\ \text{D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 from 8 to 20 inches, with + 1 D. sphere added to the cylindrical glasses.

Ophthalmoscope. M. 1 D. in the vertical meridian (90°), and emmetropia in the horizontal meridian (180°) in each eye.

The patient is now wearing — 1 D. cyl., 180°, exactly the same glasses he accepted in this test, and they were ordered continued. For reading glasses + 1 D. cyl., 90°, was ordered for each eye.

CHAPTER XII.

THE CORRECTION OF COMPOUND MYOPIC ASTIGMATISM—ILLUSTRATIVE CASES.

In testing for glasses in compound myopic astigmatism, we begin as in simple myopic astigmatism; that is, we examine the eye first with the ophthalmometer to ascertain if there is any astigmatism.

Having found the amount and meridian of the astigmatism, we next apply subjective tests with the trial case and test cards. As in all errors of refraction, where astigmatism is present, we begin the test with weak plus cylindrical glasses, unless we know beforehand the nature of the error of refraction; and plus glasses are begun with in order to avoid inciting spasm of accommodation. If the patient proves not to be hypermetropic, no harm is done and but little time lost. We then begin with weak minus cylindrical glasses at the axis indicated by the ophthalmometer, and gradually increase their strength so long as they improve vision, *being careful to stop with the weakest glass that gives the best vision.* If the vision is not brought to normal, with cylindrical glasses alone, we next add a weak minus spherical glass to the cylinder, and if it improves vision, gradually increase it until vision ceases to be improved. The weakest minus glasses that give the best vision are prescribed.

In very high degrees of myopia complicated with astigmatism, especially where the astigmatism is of small or only moderate amount, we have to correct part or most of the myopia before the cylindrical glass is appreciated when placed in front of the eye. Starting the test in the routine way in such cases, plus glasses would of course make the vision worse, and would be refused; and minus cylindrical glasses, though accepted, would not appreciably improve vision. Notwithstanding the fact that cylindrical glasses, as indicated by the ophthalmometer, do not appreciably affect the vision one way or the other, they should be left in the trial frames and minus spherical glasses added to them, rapidly increasing their strength. If the poor vision is due to myopia, and no very serious fundus changes have taken place (to cause amblyopia) the minus spherical glasses, which give the best vision, are soon found. When this point in the test is reached leave the minus spherical glasses in the trial frames and go back to the cylindrical glasses, increasing and diminishing them in strength alternately, to see if vision can be further improved; for with the myopia corrected, any change in the cylindrical glasses is more easily perceived. However, as above stated, where the myopia is large in amount, 8 D. or more, and the astigmatism small in amount, cylindrical glasses increase the vision very little when added to the spherical glasses, at times even when the astigmatism is as much as 1 D. In such cases, and particularly when the astigmatism is with the rule, and exactly at 180°, it is often best to give simple spherical glasses alone, tilting them slightly on the horizontal axis, the upper part forward, to get the necessary cylindrical effect. The patient will do this tilting himself, if it is not done for him, after wearing them for a few weeks.

The prescription of a simple spherical glass tilted on its horizontal axis is, when it can be done, advantageous in three rays; first, it is a simple glass, and not a compound lens; second, it is a lighter glass; and, third, it is cheaper than a compound lens.

We are to be guided in such instances (giving only spherical glasses where there is a large amount of myopia and only a small amount of astigmatism) by the increase of vision the cylindrical glass gives when added to the spherical glass. For example, if a patient accept a — 10 D. spherical glass and his vision is brought up to $\frac{20}{30}$ with it; and by adding a — .75 D. cyl., axis 180°, the vision is increased to only $\frac{20}{20}$ —, or not one whole line, do not give the compound glasses, but the simple — 10 D., and tilt them slightly forward on the horizontal axis.

Where the myopia is under 8 D., and the astigmatism is moderate or small in amount, and when the vision is considerably improved by the correction of this astigmatism, it is best to give a compound glass. This is the more important if the axis of the astigmatism is against the rule, for then it is difficult to obtain the proper cylindrical effect by tilting the spherical glasses.

Where there are fundus changes, vision will not, as a rule, be improved much with any glass whatever. Moreover, if the myopia is of the progressive type, glasses are of secondary importance; for, in such cases, constitutional treatment and general hygienic conditions are much more to be considered. The eyes should be given complete rest, and, if sensitive to light, tinted glasses should be worn. Children with progressive myopia should be taken from school, or be allowed to go for only one or two hours a day; for, if close application to books is persisted in, the eyes are irreparably injured by hastening the progress of the disease. See **Myopia, Progressive,** p. 8274, Vol. XI of this *Encyclopedia.*

A typical case of compound myopic astigmatism; Slight asthenopia; Vision brought up to normal with glasses.

C. A. B., aged 27, has poor vision, and slight pain in the eyes after using them for continuous close work. His eyesight has never been good but, until lately, he has been free from asthenopia.

Ophthalmometer. Astigmatism with the rule, 2.50 D., axis 90° + or 180° — in each eye.

Test cards and trial lenses. The vertical lines on the clock-dial are plainest, though none of them are distinctly visible.

$$\text{R. V.} = \frac{10}{200} : \frac{20}{20} + \text{W.} - 3.50 \text{ D.} - 2.50 \text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{20} + \text{W.} - 3.50 \text{ D.} - 2.50 \text{ D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 from 4 to 20 inches.

Ophthalmoscope. M. 5 D. in the vertical meridian (90°), and M. 3 D. in the horizontal meridian (180°), in each eye. The fundus in each eye is normal.

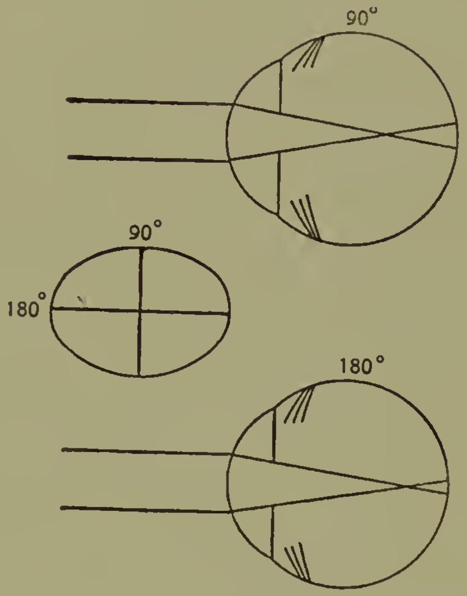

Fig. 85.

Five days later a second test was made. The ophthalmoscope and ophthalmometer showed the same condition as at the first test.

Test cards and trial lenses.

$$\text{R. V.} = \frac{10}{200} : \frac{20}{20} + \text{W.} - 3 \text{ D.} - 2.25 \text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{20} + \text{W.} - 3 \text{ D.} - 2.25 \text{ D. cyl., } 180^\circ.$$

These last glasses were ordered. They gave relief from his asthenopia, and are worn with great satisfaction and comfort. We may say that the usual routine method just described was followed in testing this case.

Compound myopic astigmatism; The myopia considerable and the astigmatism small in amount. Slight asthenopia, with poor vision.

A. C., aged 28, in good general health, has defective eyesight and occasional headaches over the brows. She is a member of a myopic family.

Ophthalmometer. Astigmatism with the rule, 2 D., axis 80° + or 170° — right eye; 2 D., axis 100 + or 10° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{6}{200} : \frac{20}{30} \text{ W.} - 5 \text{ D.} - 1.50 \text{ D. cyl., } 170^\circ.$$

$$\text{L. V.} = \frac{4}{200} : \frac{20}{30} \text{ W.} - 5 \text{ D.} - 1.50 \text{ D. cyl., } 10^\circ.$$

Reads Jaeger No. 1, 5 to 15 inches.

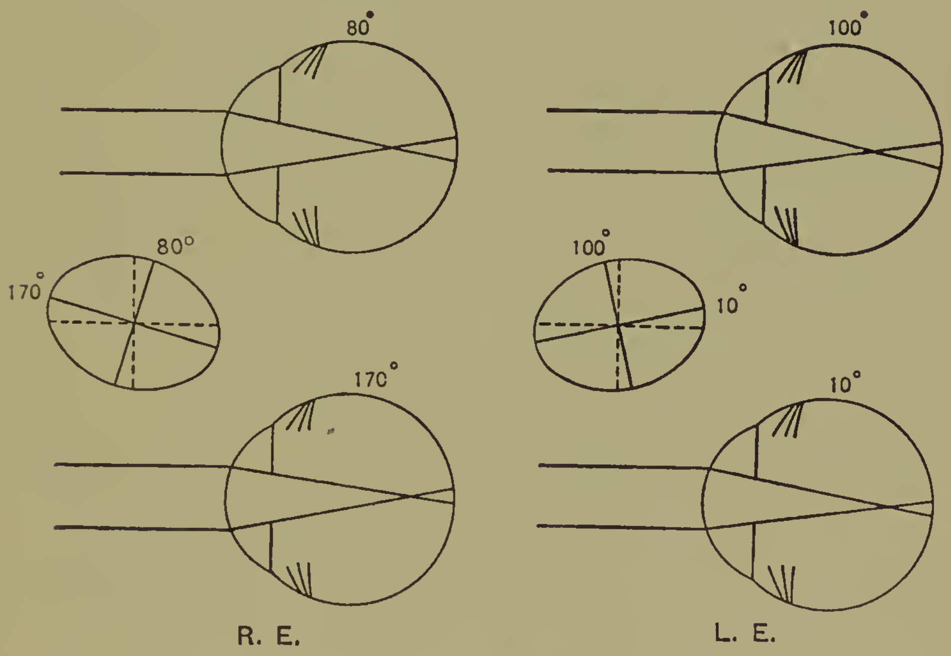

Fig. 86.

Ophthalmoscope. M. 7 D. at 80° and 5 D. at 170° right eye; M. 7 D. at 100° and 5 D. at 10° left eye.

There is a narrow crescent at the temporal side of the disk in each eye.

On second test the patient accepted the same glasses as at the first. These were ordered and gave satisfaction for more than three years.

Compound myopic astigmatism, the myopia being large in amount, while the astigmatism is small in amount.

Miss E. E. D., in fairly good health only, came on account of poor vision. There is no asthenopia. She belongs to a myopic family, and her sight has been poor from childhood.

Ophthalmometer. Astigmatism with the rule, 2.25 D., axis 100° + or 10° — right eye; 2.25 D., axis 75° + or 165° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{4}{200} : \frac{20}{70} \text{ W.} - 16 \text{ D.} - 1.25 \text{ D. cyl., } 10^\circ.$$

$$\text{L. V.} = \frac{4}{200} : \frac{20}{70} \text{ W.} - 16 \text{ D.} - 1.25 \text{ D. cyl., } 165^\circ.$$

Reads Jaeger No. 1 at 7 inches, with — 10 D. spherical glass in each eye.

Ophthalmoscope. Myopia of 16 D. in each eye. There is a large posterior staphyloma in each fundus, but comparatively few choroidal changes considering the high degree of myopia.

A second test resulted in acceptance of the same glasses as at first; ordered — 16 D. for the distance in the form of a hand-lorgnon and — 10 D. for close work.

In this case the myopia was so great and the amblyopia so marked and the indicated cylinder improved vision but little, that it was not added to the spherical glass, especially as the latter was already very heavy. As stated, it often happens, in these cases of high degree of myopia, that the patient is not able to wear the full correction, even on the street. In such instances we must reduce the power of the glass if we give it for constant wear; or give full strength in a lorgnon, to be used for only a few moments at a time, when the patient wishes to see distinctly.

Patients who have worn strong concave glasses from childhood can wear a much nearer approach to their full correction, in these high degrees of myopia, than those who have worn very weak glasses, or none at all till later years. The reasons for this are: first, in those who wore glasses that corrected most of their myopia the ciliary muscle had to be used when looking close at hand, and in this way it developed; and strong glasses can on this account be worn without fatigue. But in those who have not worn for the distance their full correction, or have worn no glasses at all, the ciliary muscle remains undeveloped from non-use; and when strong glasses are prescribed, requiring the use of the ciliary muscle for near work, the eyes easily tire. In the second place, the distorting and reducing effects of strong concave glasses are not much noticed by a child in early life, and he grows accustomed to the effects as natural ones; while these effects later in life are very annoying, so much so that in many cases patients will not tolerate anything like their full correction. These facts should be taken into consideration, and a reduction in the strength of strong concave glasses be made to secure comfort for the patient.

The writer has in mind one patient who accepted — 17 D. and saw $\frac{20}{30}$ on the Snellen test cards and yet was unable to, or rather would not, wear them on the street, because, as she said, she could not recognize even her intimate friends in the street with them, on account of the distortion and reduced size of their features. She had been wearing — 10 D. before, and — 12 D. was the strongest she could wear with comfort, though she saw much worse with this than with the — 17 D., so far as the test cards were concerned. In very high degrees of myopia, therefore, there is no strict rule to follow except the supreme law of the best interests and the comfort of the patient. Frequently we must prescribe much less than the full correction, even for street wear, and give a still weaker glass for reading. If the patient desires a full correction give it in a lorgnon, which can generally be used for short periods with comfort and safety.

Patients with high degrees of myopia, especially those with fundus lesions, see much worse when the stomach is upset or their general condition much disturbed in any way. When general improvement occurs the vision also improves. This point is noticed here as a precaution not to be induced by the patient to change his glasses unnecessarily at such times.

The general health of all these patients should be looked after The patient being fifty years of age, was presbyopic to the extent of most carefully, outdoor exercise ordered, rest to the eyes enjoined and close work for the eye for any considerable time prohibited. In school children especially who show any tendency to progressive or malignant myopia, too much stress cannot be laid on the observance of general hygienic conditions, such as much out-of-door exercise, short hours of study under the most favorable surroundings,—good light, upright position of the child at desk, etc.; and proper correction of errors of refraction. If the patient can afford a tutor, the eyes can be relieved of a great amount of work in this way.

In any event it is much better to have these children go through school with little "book learning," than to permit the acquisition of knowledge at the expense of their eyesight.

Large amount of myopia with a moderate amount of astigmatism with the rule; Asthenopia; Relief with glasses.

K. McQ., aged 31, in good health, has poor vision and some asthenopic symptoms. She is now wearing — 9.50 D., right eye, and — 9 D. left eye.

Ophthalmometer. Astigmatism with the rule, 3 D., axis 105° + or 15° — right eye; 1.50 D., axis 90° + or 180° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{70} \text{ W. — 8 D. — 2.50 D. cyl., } 15^\circ.$$

$$\text{L. V.} = \frac{4}{200} : \frac{20}{70} \text{ W. — 11 D. — 1 D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 at 9 inches.

Ophthalmoscope. M. 11 D. at 105° and 8 D. at 15° right eye; M.

13 D. left eye. There is a small posterior staphyloma in the right eye, and a large one in the left, with spots of choroidal changes scattered over the fundus in each.

Second test: The patient accepted the same glasses as at the first test, and these were ordered.

In this case the vision was considerably improved by the addition of the cylindrical to the spherical glasses, and the full correction was ordered to be worn constantly, although the myopia was large in amount in the left eye. The glasses were worn with perfect comfort.

We here emphasize a point which has already been alluded to in this section in a general way, and that is, that the patient was able to wear these strong negative glasses for near work with comfort. This is not always so, and in her case it was due to the fact, that she had worn almost full correction for her myopia since childhood; and, having her myopia corrected for the distance, was compelled to use her accommodation for near points. In this way the ciliary muscle was developed, and when she came to use a full correction in after years, was able to wear the glasses with comfort.

Compound myopic astigmatism in one eye; Simple myopia of small amount in the other; Scopolamin used as a cycloplegic.

Miss M. R., aged 31, in good general health, came on account of burning and itching in the eyes, and for a strained feeling in them after close work. She is a stenographer, and her eyes have troubled her more or less for the past year. No headaches, but there is a mild conjunctivitis present.

Ophthalmometer. Astigmatism with the rule, .75 D., axis 90° + or 180° — right eye; .50 D., axis 90° + or 180° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{40} \quad : \frac{20}{15} \text{ W.} - 1\text{ D.} - .25\text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{30} + \ : \frac{20}{15} + \text{ W.} - .50\text{ D.}$$

Reads Jaeger No. 1, 6 to 15 inches.

Ophthalmoscope. M. 1 D., right eye; M. .50 D. left eye.

There were some redness and injection of the conjunctiva with miliary granulations on the palpebral conjunctiva. On this account and from the fact that weak minus glasses were accepted, it was thought that the myopia, as observed by the ophthalmoscope and as manifested by the glasses, was due to a spasm of accommodation, even though the patient accepted the same glass time and again during the examination.

A solution of scopolamin (one grain to a fld. oz.) one drop in each eye, was instilled every five minutes, for six consecutive times; then a wait of one-half hour and the test made, with the following result:

$$\text{R. V.} = \frac{20}{100} : \frac{20}{15} - \text{W.} - .75\text{ D.} - .50\text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{100} : \frac{20}{15} - \text{W.} - .25\text{ D.} - .25\text{ D. cyl., } 180^\circ.$$

The ophthalmoscope and ophthalmometer gave the same results as at the first test.

Third test, three days later, when the patient was not under the influence of the cycloplegic, resulted as follows:

$$\text{R. V.} = \frac{20}{40} : \frac{20}{15} - \text{W.} - .75\text{ D.} - .50\text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{15} \quad \text{W.} - .50\text{ D.}$$

Reads Jaeger No. 1, 6 to 15 inches.

These glasses were ordered, and have since been worn with comfort and satisfaction.

In very low degrees of myopia, it is impossible at times to decide with the ophthalmoscope or the retinoscope (without the use of a cycloplegic) whether myopia is present or not. The mere acceptance of minus glasses by a patient is not positive evidence by any means that myopia exists; as hypermetropes, through spasm of accommodation may, and often do, when improperly tested, accept minus glasses. Myopia of a low degree, 1 D. and less, rarely needs correction, unless there is a complicating astigmatism.

Compound myopic astigmatism in one eye; Simple myopic astigmatism in the other; Asthenopia marked; Presbyopia.

Mrs. M. S. C., aged 50, in good general health, came on account of headaches and pains in the eyes, especially after close work. She has worn glasses for fifteen or twenty years, constantly for the last ten years.

Ophthalmometer. Astigmatism with the rule, 4 D., axis 125° + or 35 — right eye; 4 D., axis 55° + or 145° — left eye.

There is also some irregular astigmatism in the right eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{50} + \text{W.} - 3.50\text{ D. cyl., } 35^\circ.$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{20} - \text{W.} - 4\text{ D.} - 3.50\text{ D. cyl., } 145^\circ.$$

Reads Jaeger No. 1, 6 to 13 inches with + 2 D. added for the presbyopia, which in effect would be: + 2 D. — 3.50 D. cyl., 35° right, and — 2 D. — 33.50 D. cyl., 145° left.

Ophthalmoscope. M. 4 D. at 125° and Em. at 35° right eye; M. 8 D. at 55° and 4 D. at 145° left eye.

There are some diffuse opacities on the right cornea, which accounts for the unimproved vision in that eye.

A second test was made and agreed with the first, and both distance and reading glasses were ordered. Both pairs of glasses have been worn with comfort.

It is to the reading glasses we wish to call attention in this case. 2 D. In the right eye she had simple myopic astigmatism, and either a cross-cylinder or a sphero-cylindrical glass could be given. If a cross-cylindrical glass, it would take the following form: + 2 D. cyl., 125° — 1.50 D. cyl., 35°. A glance at Fig. 83 shows why this is so. The emmetropic meridian at 35° becomes presbyopic by 2 D., and requires + 2 D. cyl. at right angles to this meridian (at 125°) to correct it; while the presbyopia of 2 D. neutralizes 2 D. of the 3.50 D. of myopia in the meridian at 125°, thus leaving 1.50 D. of myopia in this meridian still to be corrected, which requires — 1.50 D. cyl., 35°. Instead of giving the cross-cylinder we chose the sphero-cylindrical + 2 D. — 3.50 D. cyl., 35°; first, because it was cheaper, second, because the astigmatism was not very large in amount, and the sphero-cylindrical glass in the right eye was made equal in weight with the opposite glass in the left eye.

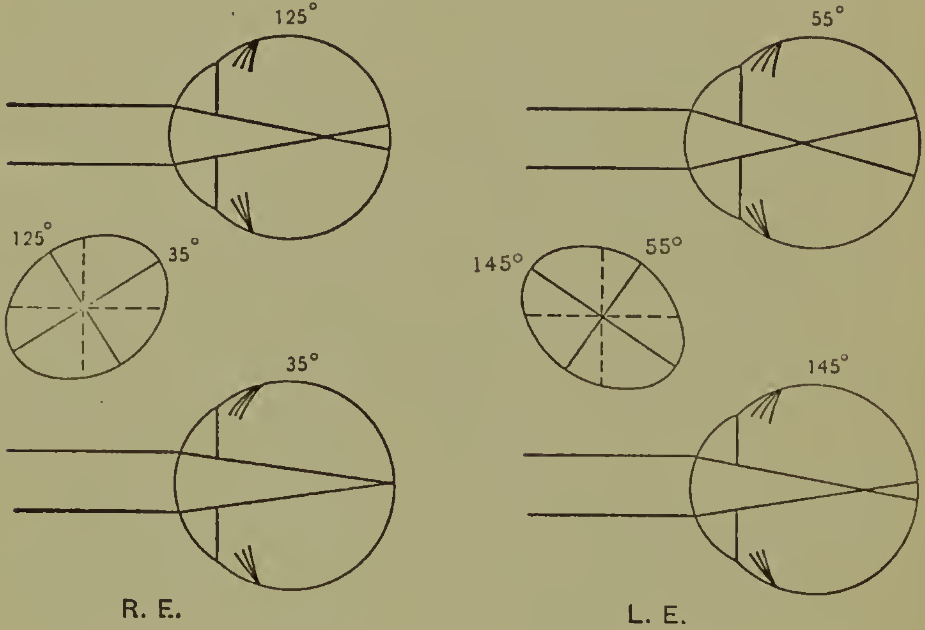

Fig. 87.

The two glasses, the cross- and the sphero-cylinders are exactly the same in effect, except that the cross-cylinders give a little wider field of vision. Thus the + 2 D. spherical glass combined with the — 3.50 D. cyl., 35°, acts with full force along the axis of the minus cylinder, that is, in the meridian at 35°, therefore acting as a + 2 D. cyl., axis 125°; and, at the same time, it neutralizes 2 D. of the 3.50 D. cyl., in the meridian at 125°, leaving but 1.50 D. of this cylindrical glass to act in this (125°) meridian, thus acting exactly the same as a — 1.50 D. cyl., 35°.

We are aware that this method of making diagrams of the foci of the chief meridians of the eye for the distance, then noting the change in focus brought about in each meridian for a certain amount of presbyopia, takes more time than the one of simple algebraic equations; but it has the great advantage of fixing the examiner's attention on the real condition and foci at the different meridians of the eye, thus making it a concrete case. With algebraic equations to ascertain the correct reading glass, it becomes a matter of abstract fact to a certain extent, and the observer, if he be a beginner, does not keep in mind the real condition of the eye, but fits the glasses empirically. For example, take the left eye in the case where the distance glass accepted is — 4 D. — 3.50 D. cyl., 145°. At fifty years of age, with 2 D. of presbyopia present, the patient requires + 2 D. added to the distance glasses to get the correct reading glass.

Algebraically it is:

— 4 D. — 3.50 D. cyl., 145°.
+ 2 D.
………………….(I)
— 2 D. — 3.50 D. cyl., 145°.

For 4 D. of presbyopia it would be:

— 4 D. — 3.50 D. cyl., 145°.
+ 4 D.
………………….(II)
— 3.50 D. cyl., 145°.

Now this is perfectly correct in each instance, but if the examiner is not quite familiar with physiologic optics, unless he makes a diagram of the change of focus brought about by the presbyopia for the reading point, he will be less likely to have a clear idea of the real condition of the eye.

Compound myopic astigmatism against the rule; Headaches; Relief with glasses.

A., aged 13 years, complains of poor vision and headaches when he studies or reads.

Ophthalmometer: astigmatism against the rule, right eye (corneal), 75 D. axis 180° + 90° — (lenticular) negative; left eye, astigmatism against the rule (corneal), .50 D. axis 180° + 90° — (lenticular) negative.

Test cards and trial lenses.

$$\text{R.V.} = \frac{20}{100} : \frac{20}{20} + \text{W.} - .50\text{ D.} = -\ 75\text{ cyl., }90°.$$

L. V. = $\frac{20}{70}$: $\frac{20}{20}$ + W. — .50 D. = — 50 cyl., 90°.

Reads Jaeger No. 1 from 4 to 16 inches.
Ad. 12°; ab. 4°, surs. R. & L. 2°.

Ophthalmoscope shows M. .50 at 90°, and M. 1 D. at 180°, each eye. The retinoscope also confirms the subjective test. A second test resulted in the patient accepting the same glasses, and they were ordered. The patient returned because his vision for the distance was greatly reduced. On examination it was found that the myopia had increased to 1.50 D. in each eye; and the astigmatism in the left to .75 D. The ophthalmoscope and retinoscope confirmed the subjective tests. The glasses were ordered.

Ophthalmometer gives the same reading as two years previously.

Test cards and trial lenses.

R. V. = $\frac{20}{200}$: $\frac{20}{15}$ — W. — 1.50 D. = — .75 cyl., 90°.

L. V. = $\frac{20}{200}$: $\frac{20}{15}$ — W. — 1.50 D. = — .75 cyl., 90°.

Reads Jaeger No. 1 from 4½ to 17 inches.

Compound myopic astigmatism, axis 120° in each eye; Relief with glasses.

Mrs. I. V. E., aged 40.

Ophthalmometer: astigmatism against the rule, 0.75 D., axis 30° + or 120° —, right eye; 1 D., axis 30° + or 120° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{18}{200}$: $\frac{20}{15}$ + W. — 2.00 D. = — 1 cyl., 120°.

L. V. = $\frac{18}{200}$: $\frac{20}{15}$ + W. — 2.00 D. = — 1.50 cyl., 120°.

Ophthalmoscope shows M. 2 D. at 90°, and 3 D. at 180°, each eye. *Retinoscope* confirms subjective test. The patient is now wearing: — 2.50 sphere, right eye; — 2.75 sphere, left eye.

Ophthalmometer records the same reading as at first test.

Test cards and trial lenses.

R. V. = $\frac{18}{200}$: $\frac{20}{15}$ W. — 2 D. = — .75 cyl., 120°.

L. V. = $\frac{18}{200}$: $\frac{20}{15}$ W. — 2 D. = — 1.25 cyl., 120°.

Reads Jaeger No. 1 from 6 to 20 inches.
Ad. 7°, ab. 5°; surs. R. & L. 1°.

Ordered: — 1.75 D. = — .75 cyl., 120°; — 1.75 D. = — 1.25 cyl., 120°.

Ophthalmometer gives the same reading as 8 years previously.

Test cards and trial lenses.

R. V. = $\frac{18}{200}$: $\frac{20}{20}$ W. — 2 D. = — 1 cyl., 120°.

L. V. = $\frac{18}{200}$: $\frac{20}{20}$ W. — 2. D. = — 1 cyl., 120°.

Reads Jaeger No. 1 from 6 to 18 inches, W. — 2 D. deducted.

Some floating opacities in left eye. Ordered simple cylinders for reading and to continue old glass for the street.

CHAPTER XIII.

ANTIMETROPIA AND ANISOMETROPIA. ILLUSTRATIVE CASES.

Antimetropia in a literal sense means an *opposed* state of refraction in the two eyes; hypermetropic in one eye, and myopic in the other. The word, however, is often used to indicate an *unequal* refraction in the two eyes.

True antimetropia, that is, an opposite state of refraction in the two eyes, is perhaps the most difficult refractive error one has to deal with; especially when one eye has a large error of refraction with marked amblyopia, while the other has a small error with fairly good vision.

Single, binocular vision is secured only with great effort (often not at all), one eye alone being used, or the eyes are used alternately. In the latter instance the patient is fortunate at times in that he can use the hypermetropic eye for distant vision and the myopic eye for near vision and without diplopia. In this he may go without glasses, and make this condition, which is a veritable burden to many, a real advantage rather than a disadvantage. See **Anisometropia.** There are several reasons why antimetropes have difficulty in using the eyes together. First, the images in the two eyes are so different in size; it is only with great effort that they are fused into a single image; second, it is more difficult to converge the myopic eye than the hypermetropic eye and fixation is made with effort; third, if the myopia is of very high degree and fully corrected the patient will have trouble with that eye in accommodating for the near-point.

The best plan of procedure in antimetropia is to correct the refractive error of each eye separately, just as in other cases, and to prescribe the glasses as accepted. Have the patient wear the glasses faithfully for a few weeks; if they do not give relief, correct the better eye, and place a plane glass on the opposite eye.

Each case must be dealt with individually, however, and there is no set rule to go by.

A few illustrative cases will indicate how such patients are to be dealt with.

Antimetropia with blepharitis marginalis; Simple hypermetropic astigmatism in one eye and simple myopic astigmatism in the other; Astigmatism with the rule in each eye.

N. R., aged 22, in good general health, came on account of great pain in the eyes, accompanied by severe headaches, and to be relieved

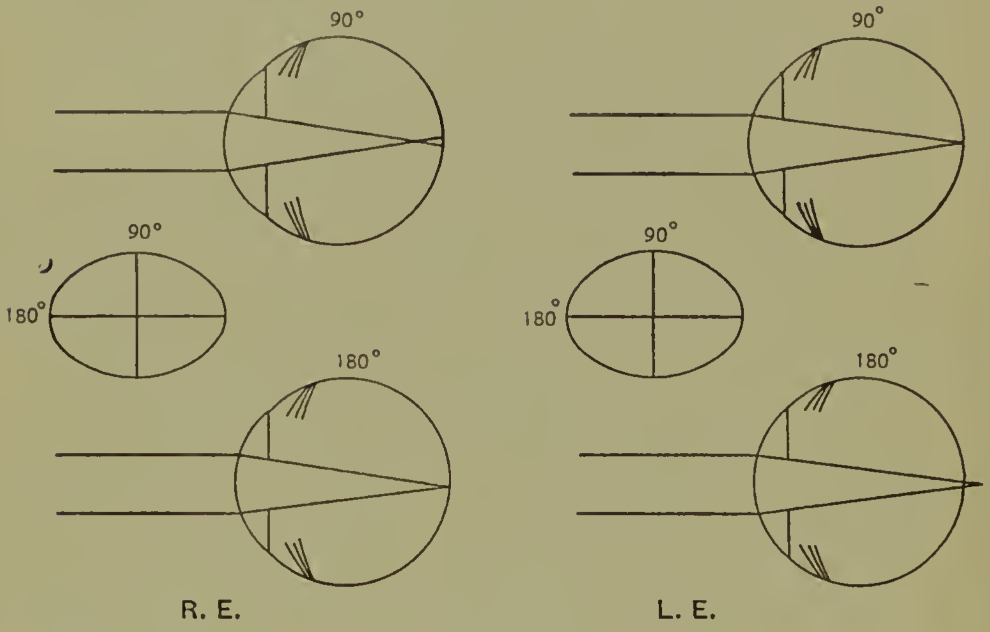

Fig. 88.

of red lids, which were irritated and inflamed all the time.

Ophthalmometer. Astigmatism with the rule, 1 D., axis 90° + or 180° — in each eye.

Test cards and trial lenses. The vertical lines on the clock-dial were plainest with the right, and the horizontal lines were plainest with the left eye.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{15} \text{ W.} - .50 \text{ D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{20} + : \frac{20}{15} \text{ W.} + .50 \text{ D. cyl., } 90^\circ.$$

Reads Jaeger No. 1 from 6 to 17 inches.

Ophthalmoscope. M. .75 D. at 90° and Em. at 180° right eye; Em. at 90° and H. .75 at 180° left eye.

The lids were treated, and when some better a second test was made for glasses. The patient accepted exactly the same glasses as at the first test and were ordered for constant wear: — .50 D. cyl., 180° right eye, and + .50 D. cyl., 90° left eye. Within a month the eyelids were well, and the pains in the eyes and the headaches gone.

With larger errors of refraction of this nature, however, glasses do not usually give so good a result.

Antimetropia; Slight amblyopia; Simple hypermetropic astigmatism in one eye, simple myopic astigmatism in the other, with the rule in each.

M. F., aged 18, in good health, came for glasses on account of poor vision, ocular pains and headaches when she persists in using her eyes.

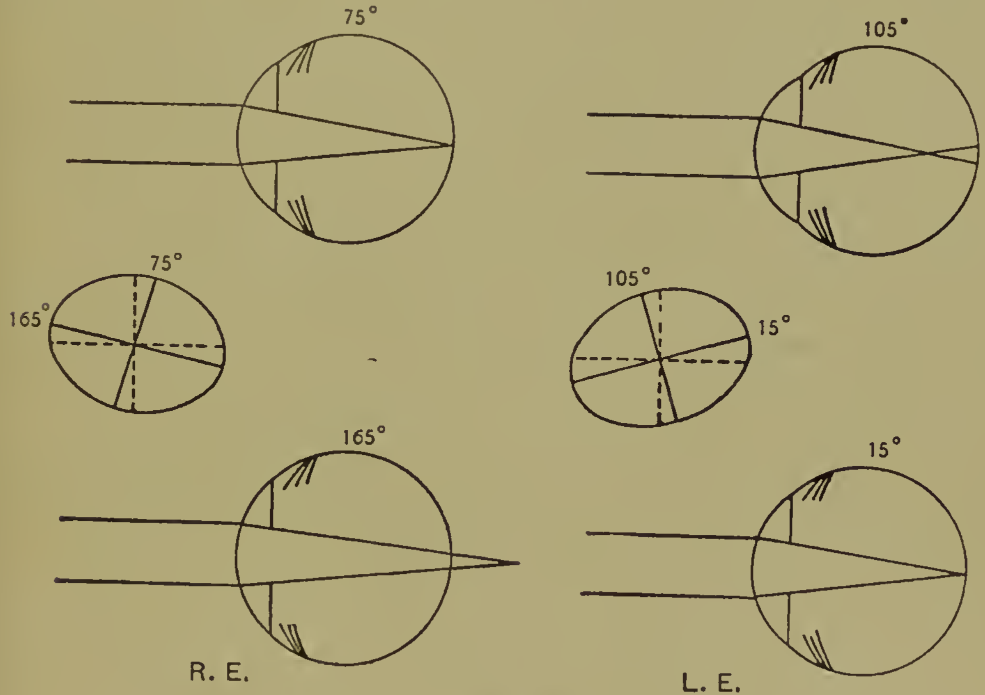

Fig. 89.

Ophthalmometer. Astigmatism with the rule, 2 D., axis 75° + or 165° — right eye; 2 D. with the rule, axis 105° + or 15° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{70} : \frac{20}{40} \text{ W.} + 1.75 \text{ D. cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{40} \text{ W.} - 1.75 \text{ D. cyl., } 15^\circ.$$

Reads Jaeger No. 1 from 6 to 12 inches, and has single binocular vision.

Ophthalmoscope. Em. at 75° and H. 2 D. at 165° right eye; M. 2 D. at 105° and Em. at 15° left eye.

A second and a third test resulted in the patient accepting the same glasses as at the first test. Ordered + 1.75 D. cyl., 75° right eye; — 1.75 D. cyl., 15° left eye. These glasses were worn for more than a year, with relief from her asthenopic vision.

Antimetropia; Compound hypermetropic astigmatism in one eye and compound myopic astigmatism in the other, against the rule in the myopic eye and with the rule in the hypermetropic eye; Marked asthenopia relieved with glasses.

H. W., aged 12, in good health, comes on account of blurred vision and headaches, especially annoying in the afternoon at school. She has worn glasses, but without relief.

Ophthalmometer. Negative, right eye; astigmatism with the rule .75 D., axis 90° + 180°, left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{70}$: not improved.

L. V. = $\frac{20}{30}$: $\frac{20}{20}$ W. + 1 D.

Reads Jaeger No. 1 from 5 to 12 inches. Signs of spasm of accommodation are present.

Ophthalmoscope. M. 1 D. right eye; H. .50 D. at 90° and H. 1 D. at 180° left eye.

On account of a conjunctivitis, an astringent wash was ordered for the eyes, and the patient directed to come again in three days.

Second test: The ophthalmometer read the same as at the first test.

Test cards and trial lenses.

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ W. — .50 D. — .50 D. cyl., 105°.

L. V. = $\frac{20}{30}$: $\frac{20}{15}$ W. + .50 D. + .50 D. cyl., 90°.

Reads Jaeger No. 1, 5 to 15 inches.

Ophthalmoscope. M. .50 D. at 105° and M. 1 D. at 15°, right eye; H. .50 D. at 90° and H. 1 D. at 180° left eye.

On a third test the patient accepted the same glasses as on the second test, and they were accordingly ordered. These glasses have been worn for more than two years with relief from all asthenopic symptoms.

In this case the ophthalmometer showed no corneal astigmatism in the right eye; and, as usual in such cases, the patient accepted a cylindrical glass against the rule. (See Fig. 90).

Antimetropia; Mixed astigmatism right, and compound myopic astigmatism left eye; Head carried to the right side; Asthenopia; Relief with glasses.

M. McG., aged 23, in good health, has headaches and pains in the eyes. She has a tendency to hold her head to the right, especially for close work. Her left eye has troubled her a great deal for the last eighteen months, and sometimes sharp pains shoot through it. The left eye is very sensitive to bright light and heat.

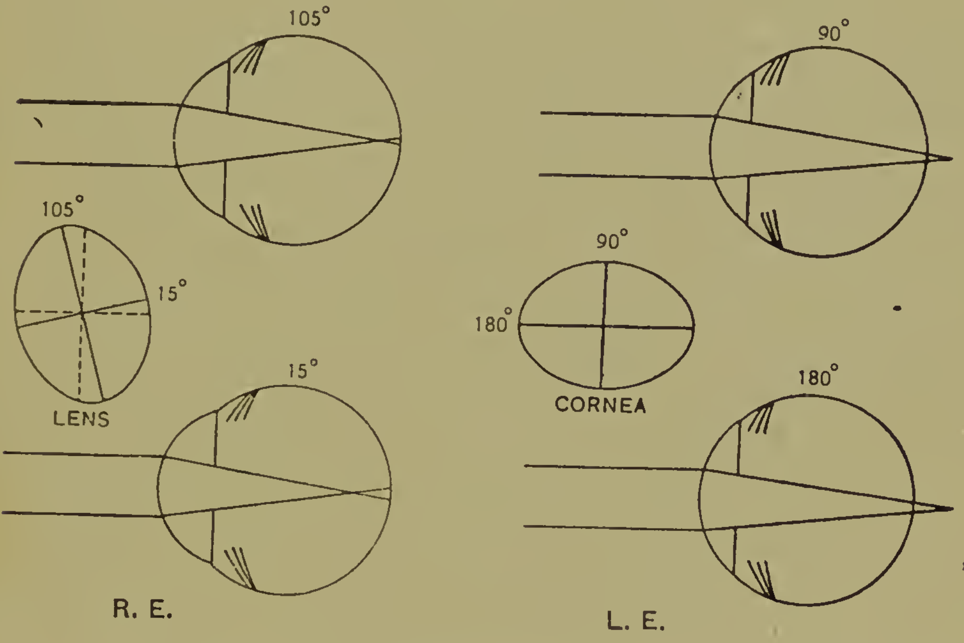

Fig. 90.

Ophthalmometer. Astigmatism with the rule, 2.50 D., axis 45° + or 135° —, right eye; 2.50 D., axis 60° + or 150° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{40}\ \text{W.} + 2\ \text{D. cyl., } 45° - .50\ \text{D. cyl., } 135°.$$

$$\text{L. V.} = \frac{1}{200} : \frac{20}{100}\ \text{W.} - 10\ \text{D.} - 2\ \text{D. cyl., } 150°.$$

Reads Jaeger No. 1, 6 to 10 inches, with the right eye. Single binocular vision is not present.

Ophthalmoscope. H. 1 D. at 135° and M. 1 D. at 45° right eye; M. 13 D. at 60° and 11 D. at 150° left eye.

Second test: two days later the ophthalmometer gave the same reading.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{40} + \text{W.} + 1\ \text{D. cyl., } 45^\circ - 1\ \text{D. cyl., } 135^\circ.$$

$$\text{L. V.} = \frac{2}{200} : \frac{20}{100}\ \text{W.} - 10\ \text{D.} - 2\ \text{D. cyl., } 150^\circ.$$

A third test coincided with the second, and the glasses were ordered. The patient has been greatly benefited, the pain in the eyes and head disappeared after about two weeks' time; and after the first month she has been able to hold her head straight. She wore these glasses continuously for a year, when she returned, complaining of pain in the right eye. On examination it was found that the astigmatism had increased one-quarter of a diopter, and had changed axis to the extent of 10°, that is, from 45° to 35°, and from 135° to 125°, respectively. The patient accepted the + 1 D. cyl., 35° — .25 D. cyl., 125°, right eye. The left eye had the same refraction so the former glass was left.

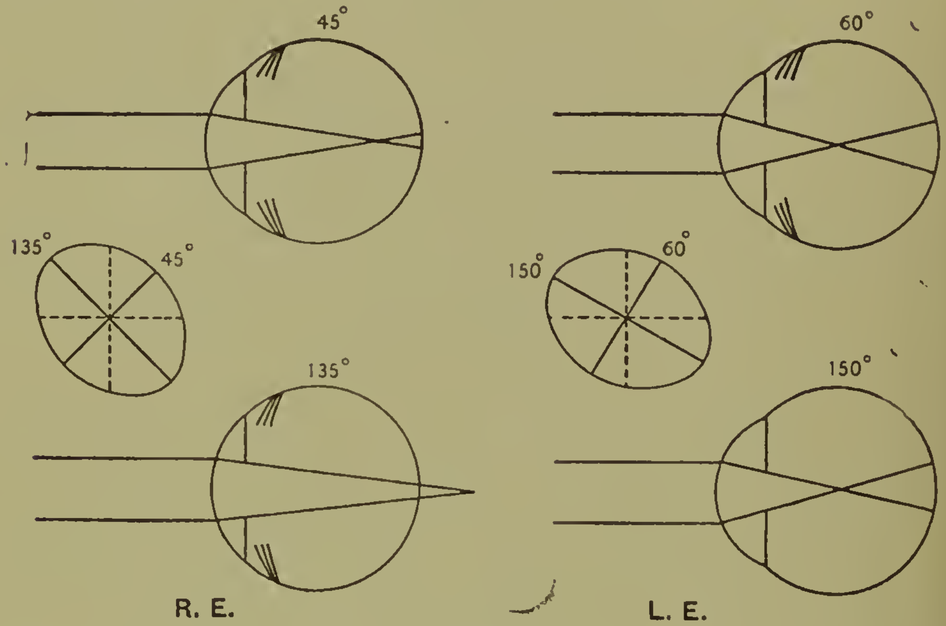

Fig. 91.

Antimetropia; Simple hypermetropia right eye; Simple myopia of large amount with convergent strabismus left eye; Correction of strabismus with glasses without operation.

E. S., aged 18, in poor health, came on account of trachoma and convergent strabismus of the left eye. She was anemic and much run down, had but poor appetite, and was under treatment for "nervous dyspepsia." There is considerable inflammation of the lids, with some discharge.

After five months' treatment locally and generally, the first test for glasses was made.

Ophthalmometer. Astigmatism with the rule, .50 D., axis 90° + or 180° — each eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{20} + \text{W.} + 1\text{ D.}$$

$$\text{L. V.} = \frac{2}{200} : \frac{20}{200}\text{ W.} - 16\text{ D.}$$

Reads Jaeger No. 1, 6 to 15 inches, with the right eye.

Ophthalmoscope. H. 1.50 D. right eye; M. 17 D. left eye, with posterior staphyloma, choroiditis, and floating bodies in the vitreous.

Second test corresponded with the first, and + 1 D., right eye, and — 10 D., left eye, were ordered, to be worn constantly. After about six weeks' time the left or myopic eye no longer squinted, a most gratifying and unusual result, although she has not single binocular vision.

The correction of the convergent strabismus in the myopic eye by means of glasses in this case is to be accounted for in exactly the same way as the ordinary convergent squint of hypermetropia is corrected by glasses, as follows: the patient, being in poor health and having 1 D. of manifest hypermetropia in the right eye, converged the left amblyopic eye unduly inward in order to assist the accommodation in the right eye. When the manifest hypermetropia in the right eye was corrected with a plus glass, there was no need of the extra accommodative power in that eye, so the patient no longer converged the left eye too far, but relaxed this effort, and the left eye became straight.

Emmetropia right eye; Hypermetropic astigmatism, left eye; In the course of 16 years first converted into myopia, then into compound myopic astigmatism against the rule.

R. M., aged 8, for a month or two has complained of headache, diplopia and pain in the eyes.

Ophthalmometer: astigmatism with the rule, .50 D. axis 90° + or 180°—, right eye.

Astigmatism with the rule, .75 D. axis 90° + or 180° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{15}\text{ not improved.}$$

$$\text{L. V.} = \frac{20}{15} : \frac{20}{15}\text{ W.} + .25\text{ cyl., } 90°.$$

Reads Jaeger No. 1 from 4 to 15 inches.

Ophthalmoscope shows H. .50 D., each. Has slight convergence. Accepts no glasses. Ad. 11°, ab. 5° sur. R. & L. ½°. With red glass has homonymous horizontal diplopia. The patient was placed on tonics.

Later complained of some headaches and pains in the eye, also of seeing double at times.

Ophthalmometer: astigmatism with the rule, .25 D. axis 90° + or 180° —, right eye.

Astigmatism with the rule, .50 D. axis 90° + or 180° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{20} \text{ W.} - 1 \text{ D.}$$

$$\text{L. V.} = \frac{20}{50} : \frac{20}{20} \text{ W.} - 1.25 \text{ D.}$$

Reads Jaeger No. 1 from 4 to 15 inches. After two days of atropin accepted the same glasses, and the ophthalmoscope and retinoscope confirmed the subjective tests.

Ordered: — 1 D. right eye; — 1.25 D. left eye.

Four years after first test the patient accepted, right, — 1.50 D. ⊃ — 0.50 D. cyl., 105°; left, — 1.50 D. ⊃ — 0.50 D. cyl., 90°.

The following year: right, — 2.25 D. = — .75 D. cyl., 105°; left — 2.50 D. = — .75 D. cyl., 90°.

Nine years subsequent to the first visit patient accepted right, — 3.50 D. = — 1 D. cyl., 90°; left, — 3.50 D. = — 1 D. cyl., 90°.

Still complained of seeing double at times. Ad. 15°, ab. 5°, sur. R. & L. 1°.

Finally, five years after last examination the ophthalmometer showed astigmatism with the rule (corneal) .25 D., axis 90° + or 180° —, right eye; astigmatism against the rule (lenticular), .50 D., axis 180° + or 90° —, right eye; astigmatism with the rule (corneal), .25 D., axis 90° + or 180° —, left eye; astigmatism against the rule (lenticular), .50 D., axis 180° + or 90° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{15}{200} : \frac{20}{15} \text{ with } - 3.75 \text{ D.} = -.75 \text{ cyl., } 90^\circ.$$

$$\text{L. V.} = \frac{15}{200} : \frac{20}{15} \text{ with } - 3.75 \text{ D.} = -.75 \text{ cyl., } 90^\circ.$$

and these glasses were ordered.

Reads Jaeger No. 1 from 6 to 8 inches.

Ad. 19°, ab. 5°, sur. R. & L. 2°.

Ophthalmoscope shows M. 3.50 D. at 90°, and M. 4.50 D. at 180°, each eye. Retinoscope confirms the findings of the other tests.

CHAPTER XIV.

MIXED ASTIGMATISM. ILLUSTRATIVE CASES.

Mixed astigmatism is one of the most troublesome errors of refraction one is called upon to correct, and many ophthalmologists never attempt to correct a case of mixed astigmatism without the use of a cycloplegic. To beginners such cases are puzzling, and the examiner is often led to make prolonged and unnecessary tests. In the opinion of the writer, unless there is a tendency to, or an actual spasm of, accommodation, there is no more call for the use of a cycloplegic in testing a case of mixed astigmatism than there is in simpler errors of refraction.

Retinoscopy is a most valuable method of testing where a cycloplegic or mydriatic is used, but by the use of the ophthalmometer and a routine method of testing the cases, we are able, in the great majority of cases, to avoid the troublesome cycloplegic altogether.

The test in these cases is begun in exactly the same manner as in all others, that is, to ascertain with the ophthalmometer the amount and axis of the corneal astigmatism; then proceed with trial lenses, the ophthalmoscope and if necessary use a cycloplegic and the retinoscope. Suppose, for example, the ophthalmometer reads astigmatism with the rule, 2.50 D., axis 90° + or 180° —. The first glass to try is a + .25 D. cyl., 90°. If this improves vision, gradually increase its strength (+ .25 D. at a time) until the plus cylindrical glasses cease to improve the vision. By way of illustration in this hypothetical case, let us suppose, further, that the patient accepts + 1 D. cyl., 90°, and the vision is improved from $\frac{20}{100}$ to $\frac{20}{50}$, but that when a + 1.25 D. cyl., 90°, is tried it makes the vision worse. Now, since the ophthalmometer showed the patient to have 2.50 D. of astigmatism, and as he accepts only 1 D. of that amount in plus glasses, we suspect mixed astigmatism, especially if a weak plus spherical glass in addition to the cylindrical does not further improve vision. Then try a — .25 D. cyl., 180°. If this improves vision, it should be increased in strength, a quarter diopter at a time, until the vision ceases to be improved thereby, being careful to stop with the weakest minus glass that gives the best vision. We will say — 1 D. cyl., 180°, in this instance, and that the vision was further improved over that obtained by the plus cylinder alone; $\frac{20}{50}$ to $\frac{20}{30}$, with the two cylinders combined. This would indicate mixed astigmatism, equally divided as to hypermetropia and myopia, or 1 D. of each, and 2 D. of astigmatism all told. Deducting .50 D. from the reading of the ophthalmometer (which is 2.50 D.), since the astigmatism is with the rule, it leaves just 2 D. of astigmatism to be corrected; or the lenticular astigmatism may be tested objectively with the phakometer. Of course, a second test should be given in all cases of mixed astigmatism, and if the glasses on the second test agree with the first test, do not hesitate to give them. Sometimes it is necessary to give a third test. It is exceptional in the author's experience not to be able to "fit" such cases without the use of a cycloplegic.

Knowing the amount of the astigmatism from the reading of the ophthalmometer, we can readily see how close the astigmatism, as indicated by the glasses accepted, corresponds with it. In this way we are put on guard against giving too strong minus cylinders in such cases, as is often done, especially where the test is improperly begun with minus glasses.

If it is of great importance in ordinary cases to commence the test with *plus* glasses, how much more important to begin in the same way for mixed astigmatism? We must do so unless we wish to give too strong minus cylinders, or use a cycloplegic. In fact it is not so very uncommon to see cases of mixed astigmatism fitted with minus cylindrical glasses alone. So easy is it to fall into this error, that we venture to present a diagram of such a case, and in this way demonstrate how such mistakes are made and thus keep beginners from blundering.

As an example, we will take the case just cited above, where the ophthalmometer reads astigmatism with the rule, 2.50 D., axis 90° + or 180° —, and the patient accepted + 1 D. cyl., 90° — 1 D., cyl., 180°.

Now, if instead of beginning the test with weak plus cylindrical glasses, as we did, say we began with minus cylinders, and gradually increased them in strength. In place of stopping with — 1 D. cyl., 180°, the exact correction of the myopic astigmatism, the patient would most likely have accepted — 2 D. cyl., 180°, the total amount of astigmatism present. In this way the mixed astigmatism is converted into a simple hypermetropia of 1 D.

A glance at Fig. 92 shows how this is brought about. The — 2 D. cyl., 180°, not only corrects the myopia of 1 D. in the vertical meridian, but diverges the rays in that meridian 1 D. back of the retina. Now, since the eye is already hypermetropic 1 D. in the horizontal meridian, we evidently have in effect 1 D. of simple hypermetropia present; which induced hypermetropia, by the way, the patient can and often will correct by the use of the ciliary muscle, since he now can use it in its entire circumference. Not only can the patient do this, but, if his accommodative power is strong, he sometimes does it with comfort. Hence the occasional relief from asthenopia in mixed astigmatism, even with simple minus cylindrical glasses.

Incidentally it may be remarked, a case similar in effect to this is one in which a patient with simple hypermetropic astigmatism accepts a simple minus cylinder. Suppose a patient wears a + 1 D. cyl., 90°, to correct a simple hypermetropic astigmatism of that amount. Now, instead of this he will sometimes accept — 1 D. cyl., 180°, especially if in testing for glasses minus cylinders are first tried. The — 1 D. cyl., 180°, converts the patient's simple hypermetropic astigmatism into a simple hypermetropia of 1 D. (see Fig. 93).

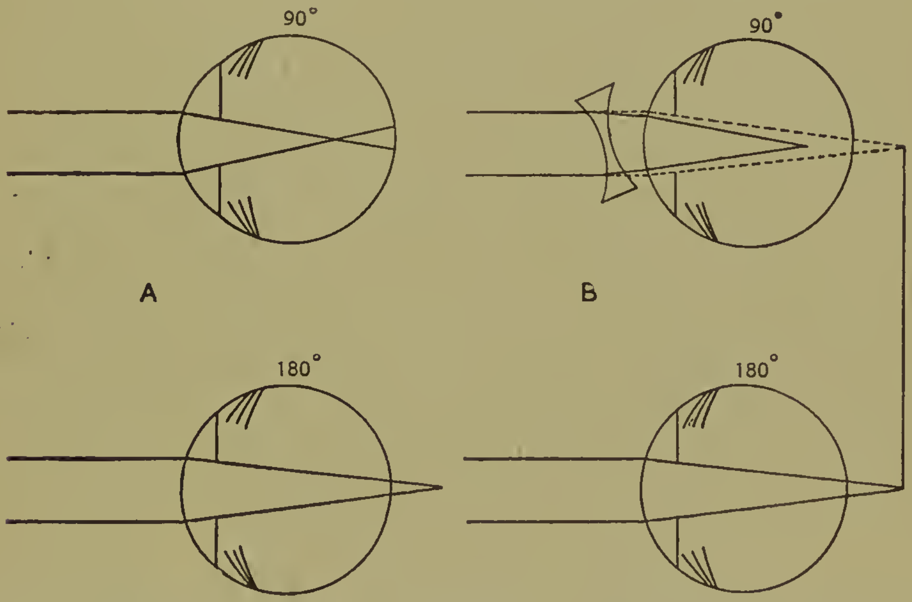

Fig. 92. *(A)* Before Correction. *(B)* After Correction with — 2 D. cyl., axis 180°, the mixed astigmatism is converted into a simple hypermetropia of 1 D.

The patient by means of his accommodative power can correct this simple hypermetropia (as shown by the minus cylinder) with comfort at times, because he can use the whole of the ciliary muscle regularly; while he could not correct the simple hypermetropic astigmatism without discomfort, since, in that case, the ciliary muscle contracts irregularly to act on the horizontal meridian of the lens without at the same time acting on the vertical meridian, which is emmetropic and whose refractive force should not be altered. Such is the simple explanation of these cases. No stronger plea could be urged for the beginning of all tests with plus glasses.

To recapitulate: most cases of mixed astigmatism can be correctly fitted with glasses without the use of a cycloplegic, provided first, that the amount and meridian of the corneal astigmatism be ascertained; next, that the test for glasses be begun with weak plus glasses and their strength gradually increased; and, finally, minus glasses tried.

The chief indication for a cycloplegic in such cases, as in all other refractive errors, is spasm of accommodation, the indications of which have already been pointed out.

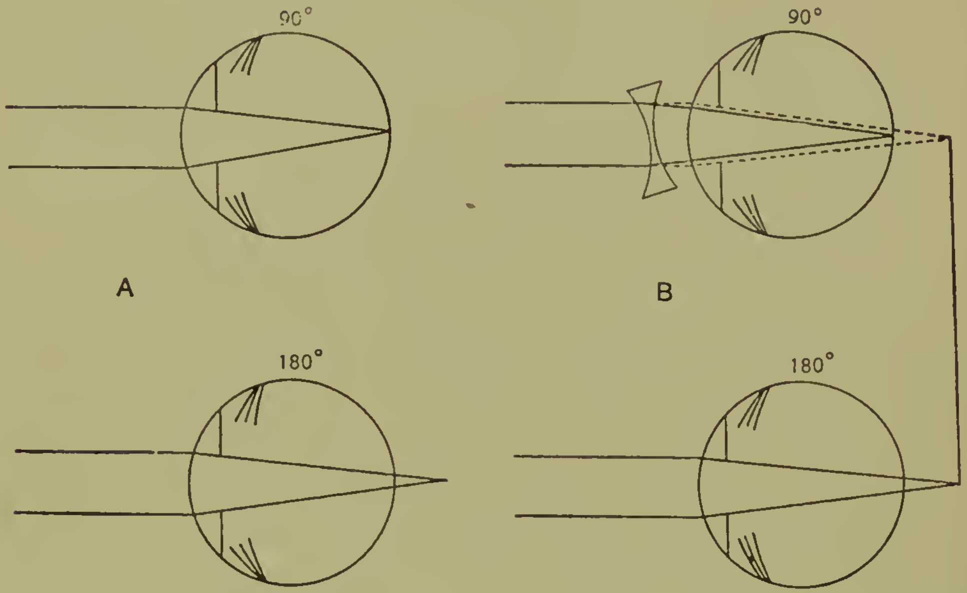

Fig. 93. *(A)* Before Correction. *(B)* After Correction with — 1 D. cyl., 180°, by which the simple hypermetropic astigmatism is converted into a simple hypermetropia of 1 D.

The following brief case-histories of cases of mixed astigmatism will serve further to illustrate the contentions of this chapter.

Mixed astigmatism of large amount and with the rule in each eye; Asthenopia; Relief with glasses.

S. A., aged 22, in good general health, has had trouble with her eyes for the past six years. She now complains of having to hold the print too close to her eyes when she reads, also of headache, and pain in the eyes after reading or sewing.

Ophthalmometer: Astigmatism with the rule, 4 D., axis 75° + or 165° —, right eye; 5 D., axis 95° + or 5° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{10}{200}$: $\frac{20}{40}$ W. + 1.75 D. cyl., 75° — 1.75 D., cyl., 165°.

L. V. = $\frac{10}{200}$: $\frac{20}{50}$ W. + 3.25 D. cyl., 95° — 1 D. cyl., 5°.

Reads Jaeger No. 1 from 8 to 15 inches.

Ophthalmoscope: M. 2 D. at 75° and H. 2 D. at 165°, right eye; M. 1 D. at 95° and H. 4 D. at 5° left eye.

Second test: Three days later the ophthalmometer gave exactly the same reading as at the first test.

Test cards and trial lenses.

R. V. = $\frac{10}{200}$: $\frac{20}{40}$ W. + 2 D. cyl., 75° — 1.50 D. cyl., 165°.

L. V. = $\frac{10}{200}$: $\frac{20}{50}$ W. + 3.50 D. cyl., 95° — .75 D. cyl., 5°.

The ophthalmoscope agreed practically with the first examination. The glasses accepted on the second test were ordered in sphero-cylinders; — 1.50 D. + 3.50 D. cyl., 75°, right; and — .75 D. + 4.25 D. cyl., 95°, left. These glasses were worn with great satisfaction from the first, and have not been changed for a period of seven years.

It will be noticed that sphero-cylinders were ordered instead of cross-cylinders. In this instance we gave sphero-cylinders, because by actual trial in the trial frames the sphero-cylinders were more comfortable to the patient and gave equally good vision. It will be seen, also, that we gave a minus sphere with a plus cylinder. There was a reason for this; the minus sphere combined with plus cylinder is a much lighter glass, in this instance. For example, take the glass for the left eye: — .75 D. + 4.25 D. cyl., 95°, is a much lighter glass than + 3.50 D. — 4.25 cyl. 5°, though both these formulæ represent glasses identical in effect.

When we have *mixed astigmatism in one eye* only and transpose a cross-cylinder into a sphero-cylinder we should pay some attention to the axis of the cylinder in the other eye, if astigmatism of a simple or compound nature is present—a point that will be illustrated by cases to follow.

In small and moderate degrees of mixed astigmatism, instead of prescribing cross-cylinders, sphero-cylinders are often to be preferred since they are optically as good as and cheaper than cross-cylinders. But in high degrees of mixed astigmatism cross-cylinders are of greater value since they allow a broader field of vision. The rule for transposing the formulæ of cross-cylinders into those of sphero-cylinders is a very simple one, the simplest of algebraic equations, but for the benefit of those who may have forgotten their algebra we shall use the simplest terms, so that this useful method may be fully understood. We shall first give a concrete example in order to illustrate the rule more plainly. Take the last case cited, right eye, where the patient accepts a + 2 D. cyl., 75° — ⊃ 1.50 D. cyl., 165°. To convert this formula into that of a sphero-cylinder (plus sphere with a minus cylinder), assume a + 2 D. sphere in place of the 2 D. cyl., then transpose 2 D. to the opposite side of the equation, changing the sign with the transposition, and add this amount (2 D.) to the — 1.50 D. cyl., which would give — 3.50 D. cyl., 165°, the axis of the minus cylinder remaining unchanged. The transposed glass is written thus: + 2 D. ⊃ — 3.50 D. cyl., 165°.

To convert this cross-cylinder into a sphero-cylinder (minus sphere with a plus cylinder) give a — 1.50 D. sphere in place of the — 1.50 D. cyl., then transpose — 1.50 D. to the opposite side of the equation, changing the sign in the transposition, and add the amount (1.50 D.) to the + 2 cyl., which would give + 3.50 D. cyl., 75°, the axis of the plus cylinder remaining unchanged. The transposed glass is indicated thus: sph. — 1.50 D. ⊃ + 3.50 D. cyl., ax. 75°.

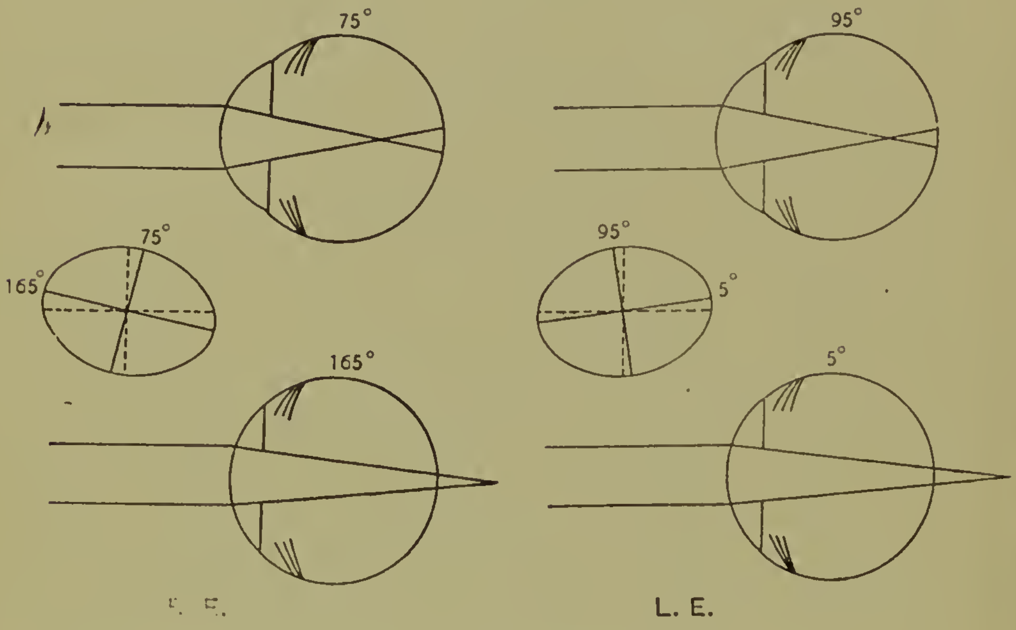

Fig. 94.

In other words, if we wish to convert a cross-cylinder into a sphero-cylinder (a plus sphere with a minus cylinder), all that it is necessary is to give in place of the plus cylinder a plus sphere of equal strength, then add this amount to the strength of the minus cylinder, leaving its axis unchanged. If we wish to convert it into a sphero-cylinder (minus sphere with a plus cylinder), all that is necessary is to write in place of the minus cylinder a minus sphere of equal strength, and add this amount to the plus cylinder, leaving its axis unchanged.

A glance at Fig. 94 will show how each of the following (three) lenses (the cross-cylinder and the sphero-cylinders into which it is capable of being converted) can correct the mixed astigmatism in the right eye. (1) + 2 D. cyl., 75° — 1.50 D. cyl., 165°; (2) + 2 D. — 3.50 D. cyl., 165°; (3) — 1.50 D. + 3.50 D. cyl., 75°.

Of glass No. 1 (the cross-cylinder) the + 2 D. cyl., 75° corrects the hypermetropia at 165° (cylinders always acting at right angles to their axes), while — 1.50 D. cyl., 165° corrects the myopia at 75°; thus the eye is rendered emmetropic, or is "corrected." In the case of glass No. 2, the + 2 D. corrects the hypermetropia at 165°; but since it acts in its whole circumference, it makes the myopia worse to that extent (2 D.) in the meridian at 75°, consequently that amount has to be added to the — 1.50 D. cyl., making it — 3.50 D. cyl., 165°. With glass No. 3, the — 1.50 D. corrects the myopia in the meridian at 75°; but here again, since it acts in its entire circumference, it makes the hypermetropia worse to that extent (1.50 D.) in the meridian at 165°; therefore that amount has to be added to the + 2 D. cyl., making it + 3.50 D. cyl., 75°.

As a rule, when transposing the formulæ of cross-cylinders into those of sphero-cylinders, the weaker cylinder should be converted into the sphere and the same amount added to the stronger; because such a combination makes a lighter glass than if the stronger cylinder were converted into a sphere and the weaker cylinder added to it. However, in making such a choice, some regard must be had to the opposite eye, if astigmatism is present in that eye, and especially if it is not of the mixed variety. Several examples will be given to illustrate further these important points.

Mixed astigmatism of large amount, with the rule; Marked asthenopia, severe headaches. dizziness; Relief with glasses.

F. E. P., aged 26, in good health, has worn glasses at times since childhood, but none of the glasses were satisfactory. When she reads, her eyes and head ache, and if she persists in reading for any considerable length of time she becomes dizzy.

Ophthalmometer: Astigmatism with the rule, 5 D., axis 105° + or 15° —, right eye; 6 D., axis 75° + or 165° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{15}{200}$: $\frac{20}{70}$ with + 1 D. cyl., 105° — 3.50 D. cyl., 15°.

L. V. = $\frac{15}{200}$: $\frac{20}{70}$ with + 1 D. cyl., 75° — 4.50 D. cyl., 165°.

Reads Jaeger No. 1, 5½ to 12 inches.

Ophthalmoscope: M. 4 D. at 105° and H. 1 D. at 15° right eye; M. 5 D. at 75° and H 1 D. at 165° left eye.

Second test: Four days later the ophthalmometer gave the same reading in the right eye, but varied 5° as to the axis in the left eye, giving 6 D., axis 70° + or 160° —.

R. V. = $\frac{15}{200}$: $\frac{20}{50}$ W. + 1.25 D. cyl., 105° — 3.25 D. cyl., 15°.

$$\text{L. V.} = \frac{15}{200} : \frac{20}{70}\ \text{W.} + 1\ \text{D. cyl., } 70^\circ - 4.50\ \text{D. cyl., } 160^\circ.$$

Reads Jaeger No. 1, 5½ to 12 inches.

This last lens was ordered as a sphero-cylinder (plus sphere with a minus cylinder). Usually, in a case with as large an amount of mixed astigmatism we prescribe cross-cylinders, because it gives a broader field of vision. But in this instance so much of the refraction is represented by a minus glass and so little by a plus lens that sphero-cylinders were prescribed. Had the hypermetropic and myopic positions of the astigmatism been nearly or exactly equal, we should have given cross-cylinders, because they would have furnished a larger field of vision than the sphero-cylinders.

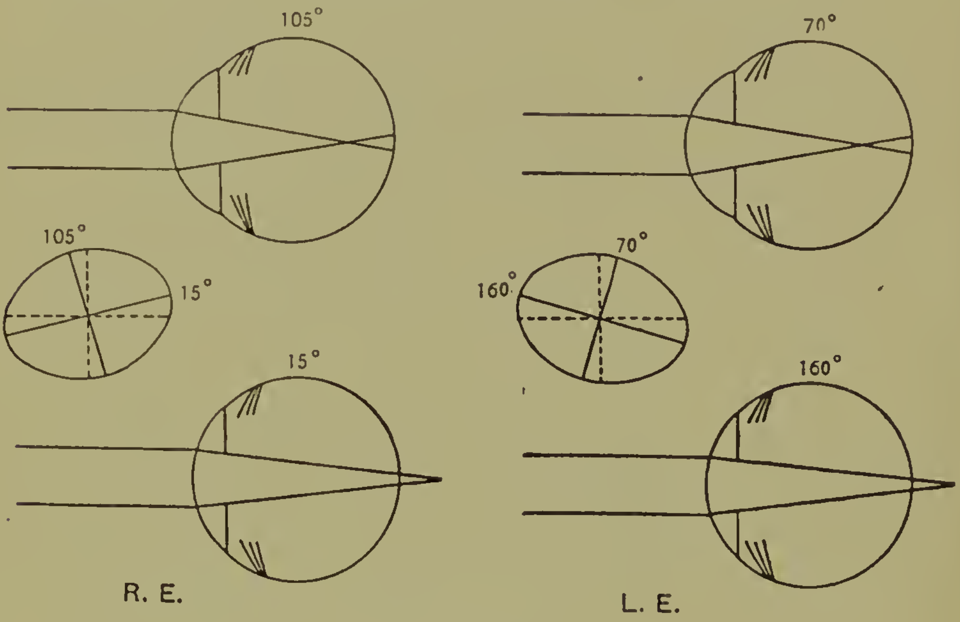

Fig. 95.

Again, in the present case, although we converted the cross-cylinders into a sphero-cylinder, we chose a plus sphere with a minus cylinder and not a sphero-cylinder with a minus sphere and a plus cylinder, because the latter choice would have made a very heavy lens, to wit: — 3.25 + 4.50 D. cyl., 105° right eye; — 4.50 D. + 5.50 D. cyl., 70° left eye.

When a cross-cylinder lens and one of the sphero-cylinders of the formula into which it can be converted do not differ much in weight, as in the cross-cylinder and the sphero-cylinder (the one with a plus sphere and a minus cylinder in the present case) we give a practical test to decide between the "fitness" of the two glasses. We first try the cross-cylinders, then the sphero-cylinders in trial frames, and ask the patient with which lenses he sees best and most comfortably; and decide accordingly. *Strange as it may seem, patients often see considerably better with one glass than the other, although in theory both lenses have the same refractive effect.*

Mixed astigmatism with the rule; No amblyopia; Persistent headaches; Relief with glasses.

A. S., aged 40, in good health, has suffered from headaches all her life. At times the headaches are very severe; in fact, neuralgic in character, and intensified by any persistent use of the eyes.

Ophthalmometer. Astigmatism with the rule, 3.50 D., axis 100° + or 10° —, right eye; 3.50 D., axis 80° + or 170° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{40} : \frac{20}{20} + \text{W.} + .75\ \text{D. cyl., } 100^\circ - 2\ \text{D. cyl., } 10^\circ.$$

$$\text{L. V.} = \frac{20}{40} : \frac{20}{20} + \text{W.} + .75\ \text{D. cyl., } 80^\circ - 2\ \text{D. cyl., } 170^\circ.$$

With both eyes at once, distant vision $= \frac{20}{15}$.

Reads Jaeger No. 1 from 8 to 18 inches.

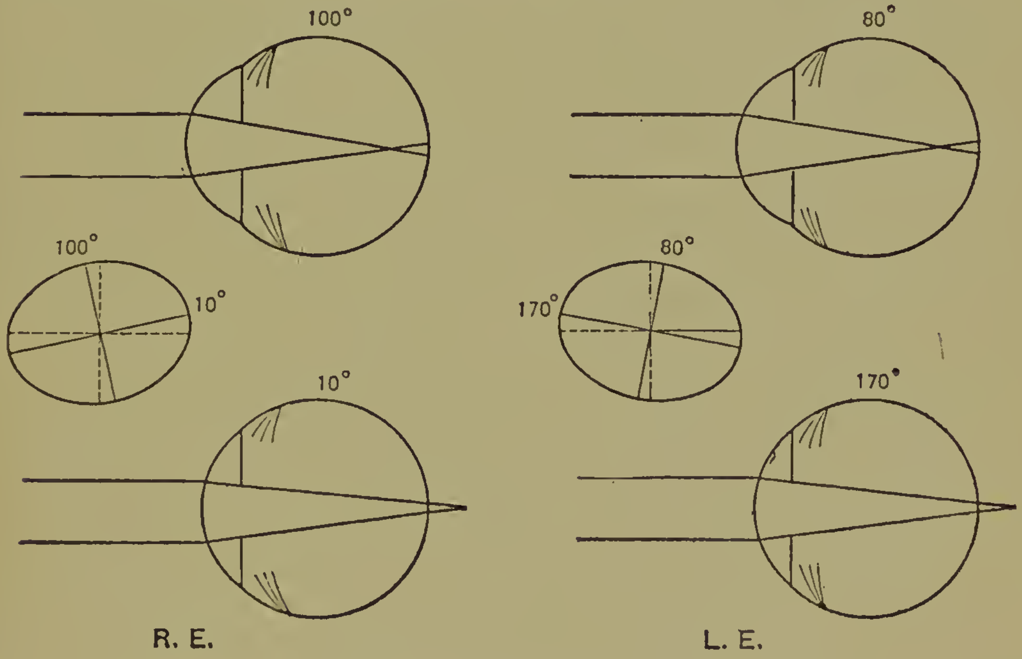

Fig. 96.

Ophthalmoscope. M. 2 D. at 100° and H. 1 D. at 10°, right eye; M. 2 D. at 80° and H. 1 D. at 170°, left eye.

These glasses in the form of sphero-cylinders (+ .75 D. — 2.75 D. cyl., 10°, right eye; + .75 D. — 2.75 D. cyl., 170°, left eye) were prescribed after one test. They gave relief almost immediately, and were worn with comfort for three years. It will thus be seen that even cases of mixed astigmatism can be "fitted" correctly, not only without the use of a cycloplegic, but at one sitting. Of course, the age of this patient favored the procedure. In patients under forty years of age that exhibit mixed astigmatism, one should always give two, and in most cases three, tests before prescribing glasses.

The sphero-cylinder with a plus sphere and a minus cylinder was more desirable than the sphero-cylinder with a minus sphere and a plus cylinder, because the former is lighter and the axes of the cylinders are horizontally placed, or nearly so.

Mixed astigmatism with the rule in one eye; Hypermetropic astigmatism with the rule in the other eye; Asthenopia; Relief with glasses.

E. R., aged 32, in perfect health, has always suffered with severe headaches and with pain in the eyes. She has been wearing glasses for the last nine months, but without much relief from her asthenopic symptoms.

Ophthalmometer. Astigmatism with the rule, 1 D., axis 80° + or 170° —, right eye; 4.25 D., axis 105° + or 15° —, left eye.

Test cards and trial lenses. The lines in the horizontal meridian from III to IX are seen plainest with the right eye. The lines from IV to X appear plainest with the left until + 1.25 D. cyl., 105°, is placed before the eye, when all of the lines appear alike, but somewhat blurred. When the entire plus cylinder, 2.75 D., is placed in front of the left eye, the lines from I to VII are seen plainest; but when — 1.50 D. cyl., 15°, is added to the plus cylinder in the frames, all of the lines appear alike and plain.

R. V. $= \frac{10}{200} : \frac{20}{70}$ W. + .50 D. cyl., 85°.

L. V. $= \frac{20}{30} : \frac{20}{15}$ W. + 2.75 D. cyl., 105° — 1.50 D. cyl., 15°.

Reads Jaeger No. 1 from 7 to 18 inches.

Ophthalmoscope. H. 1 D. right eye; H. 2 D. at 15° and M. 2 D. at 105° left eye.

Second test: the ophthalmometer reads the same exactly as at the first test.

Test cards and trial lenses.

R. V. $= \frac{20}{30} : \frac{20}{15}$ W. + .50 D. cyl., 85°.

L. V. $= \frac{10}{200} : \frac{20}{70}$ W. + 2.50 D. cyl., 105° — 1.50 D. cyl., 15°.

The ophthalmoscope agreed with the first examination. Ordered:

+ .50 D. cyl., 85° right eye;
— 1.50 D. + 4 D. cyl., 105° left eye.

We wish to call attention to two points in this case: first, the axis of the cylinder in the right eye varied 5° from the reading of the ophthalmometer; second, we converted the cross-cylinder in the left eye into a sphero-cylinder, — a minus sphere with a plus cylinder — and for three reasons: (a) to make the axis of the cylinder correspond to the right eye; (b) because, in this case, it is a lighter glass than the sphero-cylinder with a plus sphere and a minus cylinder; and (c) it is a cheaper lens.

In cases such as the present, where there is mixed astigmatism in one eye and simple or compound astigmatism in the other, in converting the corresponding cross-cylinders into sphero-cylinders, some regard must be had to the character (plus or minus) of the cylinder in the transposed glass with reference to the cylinder in the opposite eye. Because, as a rule, a plus cylinder for one eye and a minus cylinder for the other do not work as well as when both are positive or both negative. This point should be borne in mind in the conversion of cross-cylinders; unless by so doing the weight of the glass is greatly increased, cylinders of like character should be given. Sometimes it is better to prescribe the cross-cylinder in the mixed astigmatic eye (especially if the astigmatism is of large amount) rather than convert it into a sphero-cylinder, either plus sphere and minus cylinder, or minus sphere and plus cylinder. Often by placing the different combinations in front of the eye for a few moments, the patient will be able to make the choice himself.

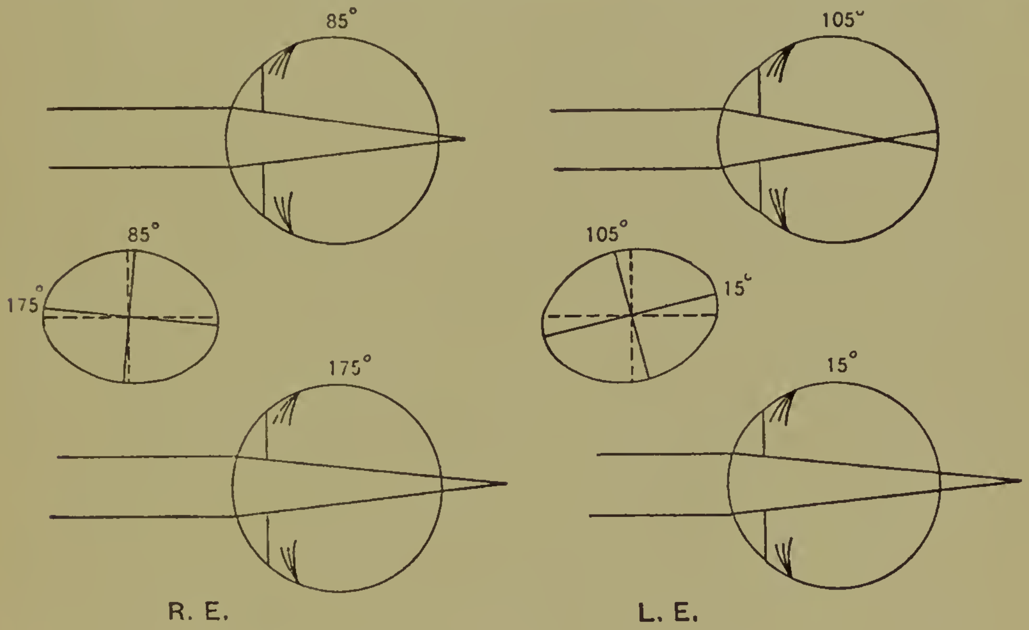

Fig. 97.

Mixed astigmatism with the rule, right eye; Hypermetropic astigmatism with the rule, left eye; Marked asthenopia; Spasm of accommodation; Atropia instilled; Relief with glasses.

P. J., aged 30, is in good general health, but has suffered a great deal from headaches and pains in the eyes. It is almost impossible for her to use her eyes for close work of any kind, because of the severe headaches and the discomfort in the eyes when she attempts such work.

Ophthalmometer. Astigmatism with the rule, 4.50 D., axis 90° + or 180° —, right eye; 1.50 D., axis 90° + or 180° —, left eye.

Test cards and trial lenses. The tests with the astigmatic clock-dial were altogether unsatisfactory, no definite result being obtained by them.

$$\text{R. V.} = \frac{10}{200} : \frac{20}{50}\ \text{W.} - 1\ \text{D.} - 4\ \text{D. cyl., } 180^\circ.$$

$$\text{L. V.} = \frac{20}{40} : \frac{20}{30}\ \text{W.} - 1\ \text{D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 from 10 to 14 inches.

With the above glasses the patient could see very well for a few moments at a time, then everything would "fade out." This happened several times during the trial when the eyes were being tested separately. It is unnecessary to say that the test in each eye was begun with the (routine) method of trying plus glasses first. As these were refused, minus glasses were next tried, with the above result.

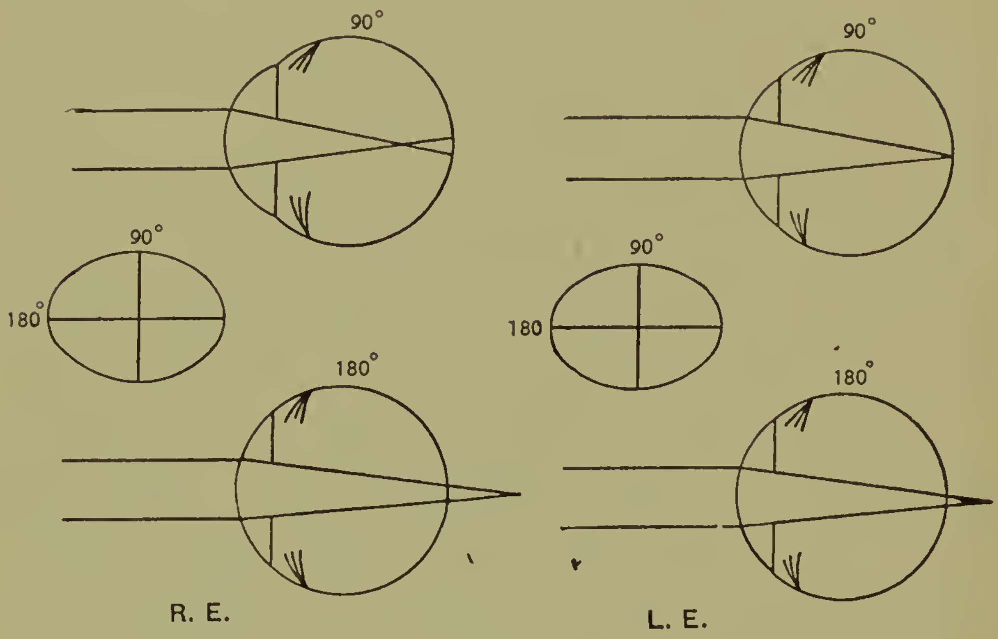

Fig. 98.

Spasm of accommodation was suspected because the patient was uncertain of the glasses, and as the letters became indistinct and illegible from time to time. The examination with the ophthalmoscope showed the patient to be a mixed astigmatic in the right eye. Retinoscopy confirmed the diagnosis of mixed astigmatism in the right eye, but the diagnosis in the left eye remained in doubt; in fact the tests indicated myopic astigmatism, which under atropin proved to be hypermetropic astigmatism.

There were no muscle insufficiencies. Atropin solution (one per cent.) was ordered, one drop into each eye three times daily for four days. Then a second test was made. The ophthalmometer gave the same readings as at the first test.

Test cards and trial lenses.

R. V. = $\frac{10}{200}$: $\frac{20}{50}$ W. + 2 D. cyl., 90° — 2 D. cyl., 180°.

L. V. = $\frac{20}{200}$: $\frac{20}{30}$ W. + 25 D. + 1.50 D. cyl., 90°.

Ophthalmoscope. H. 2 D. at 180° and M. 2.50 D. at 90°, right eye; Em. at 90° and H. 1.50 D. at 180°, left eye.

Ten days later, when the effects of the atropin had passed off, a third test was made. The subjective tests with cards and trial lenses resulted in the patient accepting the same glasses as when under the influence of atropin, except that the + .25 D. sphere was not accepted by the left eye. They were accordingly ordered, cross-cylinders, + 2 D. cyl., 90° — 2 D. cyl., 180°, right eye; and + 1.50 D. cyl., 90°, left eye. The cross cylinders in the right eye gave a broader field and more clearly defined the letters than either of the sphero-cylinders into which it could be converted. However, had either of the sphero-cylinders been ordered, it would have been a minus sphere with a plus cylinder, so that the cylinder would have corresponded both in character (plus) and in direction of axis (90°) with the cylinder in the opposite eye.

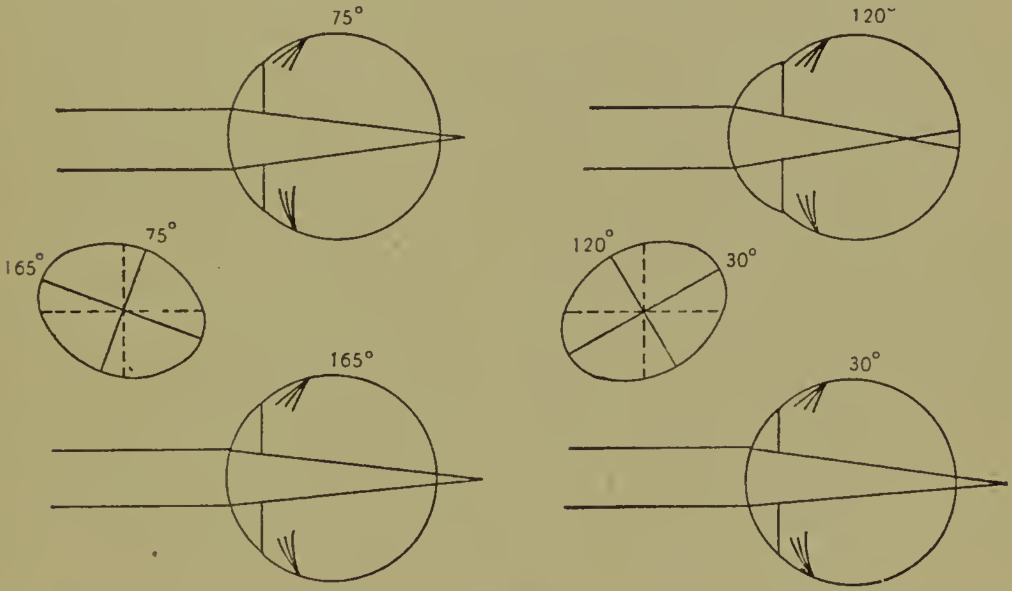

Fig. 99.

Mixed astigmatism with the rule, left eye; Compound hypermetropic astigmatism with the rule, right eye; Asthenopia; Relief with glasses.

I. S., aged 30, in good health, but has suffered considerably with headaches since her school days. She has had numerous glasses, but none have been comfortable, nor have they relieved the headaches.

Ophthalmometer. Astigmatism with the rule, 1 D. axis 75° + or 165° —, right eye; 3 D., axis 120° + or 30° —, left eye.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15} \text{ W.} + .25 \text{ D.} + .50 \text{ D. cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{100} : \frac{20}{20} \text{ W.} + 1.25 \text{ D. cyl., } 120^\circ - 1.25 \text{ D. cyl., } 30^\circ.$$

Reads Jaeger No. 1 from 5 to 20 inches.

Ophthalmoscope. H. 1 D. right eye; H. 1.50 D. at 30° and M. 1.50 D. at 120° left eye.

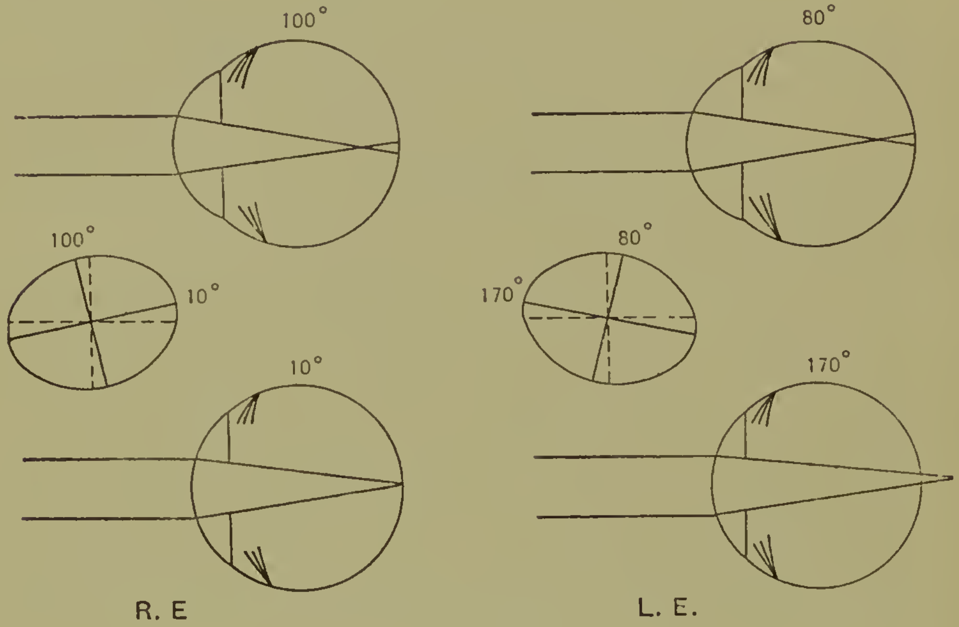

Fig. 100.

Second test: This resulted in the acceptance of exactly the same glasses as at the first test; and they were ordered:

+ .25 D. + .50 D. cyl., 75°, right eye;
— 1.25 D. + 2.50 D. cyl., 120°, left eye.

In this case, as the mixed astigmatism was not of large amount and was equally divided between hypermetropia and myopia, the cross-cylinder was converted into the corresponding sphero-cylinder, a minus sphere with a plus cylinder, so that the cylinder would exhibit the same character (plus) as the cylinder in the opposite eye. These glasses were worn with great comfort.

Mixed astigmatism with the rule, left eye; Simple myopic astigmatism with the rule, right eye; Amblyopia; Asthenopia; Relief with glasses.

G. B., aged 35, in good general health, but has been greatly troubled with his eyes for many years. He was compelled to hold reading matter very close to his eyes, and after using them for close work, vision became painful and headaches often followed.

Ophthalmometer. Astigmatism with the rule in each eye, 3.50 D., axis 105° + or 15 —, right eye; 5 D., axis 85° + or 175° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{50}$: $\frac{20}{40}$ W. — 3 D. cyl., 10°.

L. V. = $\frac{20}{100}$: $\frac{20}{50}$ W. + 2 D. cyl., 80° — 2.50 D. cyl., 170°.

Reads Jaeger No. 1 from 5 to 12 inches.

Ophthalmoscope. M. 3.50 D. at 100° and Em. at 10°, right eye; M. 3 D. at 80° and H. 2 D. at 170°, left eye.

Second test, after using an astringent wash for a week.

Ophthalmometer. Astigmatism with the rule, 3.50 D., axis 100° + or 10 —, right eye; 5 D., axis 80° + or 170° —, left eye.

The subjective test resulted in exactly the same glasses being accepted as at the first test, and they were ordered:

— 3 D. cyl., 10°, right eye;
+ 2 D. cyl., 180° — 2.50 D. cyl., 170° left eye.

Here, again, we did not convert the cross-cylinder into a sphero-cylinder, because the astigmatism was large in amount, and because by actual trial of both the sphero-cylinders into which it could be transposed, the patient saw better with the cross-cylinder. Had we given a sphero-cylinder it would have been a plus sphere with a minus cylinder, that the cylinder might correspond with the concave cylinder in the opposite eye.

Mixed astigmatism with the rule, left eye; Simple myopic astigmatism with the rule, right eye; Asthenopia; Glasses ordered without atropin.

W. G., aged 8, is in good health, but has been troubled with headaches at school. He complains also of not being able to see the blackboard.

Ophthalmometer. Astigmatism with the rule, 3.50 D., axis 105° + or 15° —, right eye; 2.75 D., 75° + or 165° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{200}$ + : $\frac{20}{40}$ W. — 3 D. cyl., 15°.

L. V. = $\frac{20}{200}$ + : $\frac{20}{40}$ W. + 1.25 D. cyl., 75° — .75 D. cyl., 165°.

Ophthalmoscope. M. 3.50 at 105° and Em. at 15°, right eye; M. 1 D. at 75° and H 1.50 D. at 165°, left eye

Second test, made after using an astringent wash for a mild conjunctivitis. The results of this test corresponded in every respect with the first test, and the glasses were ordered:

— 3 D. cyl., 15°, right eye;
+ 1.25 D. — 2 D. cyl., 165°, left eye.

These glasses were worn for more than five years, and with relief of headaches and other asthenopic symptoms.

The tender age of this patient seemed to demand a cycloplegic (and as a rule it does) especially when it was found that mixed astigmatism was present; nevertheless, he was "fitted" without it. The axis of the lens corresponded exactly with the axis indicated by the ophthalmometer in each eye; but in the left eye .75 D. was deducted from the amount instead of the usual .50 D., as ordinarily the case in astigmatism with the rule.

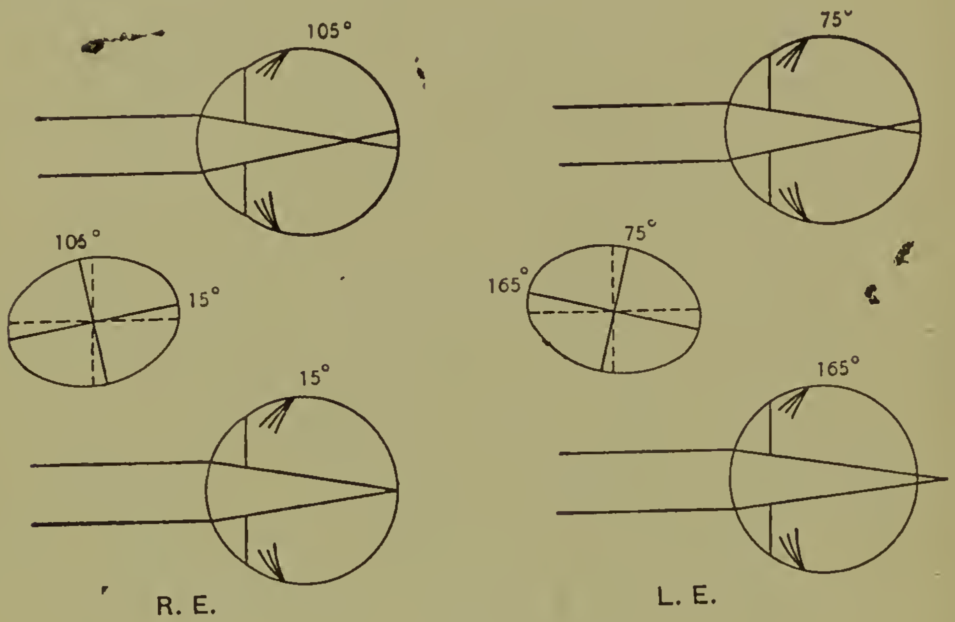

Fig. 101.

The cross-cylinder was converted into a sphero-cylinder (a plus sphere with a minus cylinder) that the cylinder might correspond in axis and character with the simple minus cylinder of the right eye. This made a slightly heavier glass than a sphero-cylinder with a minus sphere and a plus cylinder, but the importance of having both cylinders alike much compensated the slight disadvantage in weight.

Mixed astigmatism with the rule in each eye, with the meridians slanting 5° from the vertical and horizontal; Asthenopia; Relief with glasses.

D. L. B., in excellent health, but has suffered a great deal with his eyes since he was a child at school. Headaches, blurring of vision, burning of the eyelids and pains in the eyes were some of the symptoms of which he complained. He has had numerous glasses prescribed, none of which proved satisfactory.

Ophthalmometer. Astigmatism with the rule, 3 D., axis 95° + or 5° — in each eye.

Test cards and trial lenses. The lines on the clock-dial appeared with each eye to be equal but indistinct before the test began. With a plus cylinder the vertical lines seemed plainest; when the correcting minus cylinder was added to the plus cylinder the horizontal lines also came out plainly and evenly.

R. V. $= \frac{20}{200} : \frac{20}{20}$ W. + 1.50 D. cyl., 95° — 1.50 D. cyl., 5°.

L. V. $= \frac{20}{200} : \frac{20}{20}$ W. + 1.25 D. cyl., 95° — 1.25 D. cyl., 5°.

Reads Jaeger No. 1 from 3 to 16 inches.

Ophthalmoscope. M. 1.50 D. at 95° and H. 1.50 D. at 5° in each eye.

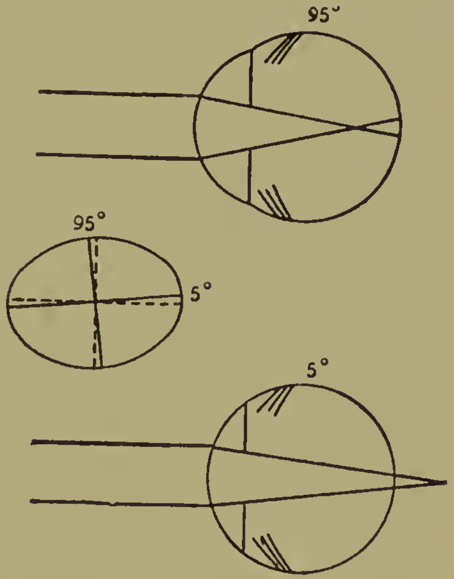

Fig. 102.

Second test, one day later, the ophthalmometer showed the same reading.

Test cards and trial lenses.

R. V. $= \frac{20}{200} : \frac{20}{20}$ + W. + 1.50 D. cyl., 95° — 1.25 D. cyl., 5°.

L. V. $= \frac{20}{200} : \frac{20}{200}$ + W. + 1.50 D. cyl., 95° — 1.25 D. cyl., 5°.

A third test confirmed the second result, and the glasses were ordered as cross cylinders. The latter were prescribed because they defined the letters better and felt easier to the eyes than the corresponding sphero-cylinders. After wearing the glasses constantly for a week the patient had relief from his asthenopic symptoms.

This patient was under observation for more than two years, during which time he wore the same glasses with continued relief. It is comparatively a rare occurrence for the axes of an astigmatism in the two eyes to slant in the *same* direction from the horizontal and vertical meridians; and when it does happen the asthenopia is usually more marked than in those cases where the axes slant an equal number of degrees in *opposite* directions from the vertical and horizontal meridians. For example, let the axis in each eye slant 15° toward the temple from the vertical meridian, in which case, in hypermetropic astigmatism, the cylinder would be worn at 105°, right eye, and 75°, left eye. In the present case both axes stand at 95°, slanting toward the temple in the right eye, and toward the nose in the left eye, or in the same direction.*

Mixed astigmatism against the rule, right eye; No corneal astigmatism, left eye, but the patient accepts a weak cylinder against the rule; Marked asthenopia; Relief with glasses.

M. M., aged 26, in only fairly good health; very nervous. Her eyes, especially the right, have given her much trouble for the last four years. She finds it almost impossible to use the eyes for close work of any kind. Not only do the eyes ache, but also her head, and often she becomes very nervous and irritable. Her mother died of consumption, but her father is still living and in good health. He wears very strong sphero-cylinders, while two brothers and a sister of the patient also wear cylindrical glasses.

Ophthalmometer. Astigmatism against the rule, 3 D., axis 175° + or 85 —, right eye. No corneal astigmatism left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{30} \quad \text{W.} + 2.50 \text{ D. cyl., } 175^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15} \text{ — W.} + .25 \text{ D. cyl., } 15^\circ.$$

Reads Jaeger No. 1 from 6 to 14 inches.

Ophthalmoscope. M. 1 D. at 90° and H. 2 D. at 180°, right eye; H. 50 D., left eye.

On account of a conjunctivitis an astringent wash was ordered, and after one week a second test was made. The ophthalmometer read the same as at the first test.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{20} \text{ W.} + 2.50 \text{ D. cyl., } 175^\circ - .50 \text{ D. cyl., } 85^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15} \text{ W.} + .25 \text{ D. cyl., } 15^\circ.$$

The ophthalmoscopic measurements agreed essentially with those of the first examination.

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* For discussion of the relative position of the axes of cylindric glasses, see Claiborne, *New York Med. Journal,* June 25, and July 2, 1892; Knapp, *Trans. Amer. Opthal. Soc.,* Vol. VI, p. 308, 1892; and Snellen, Graefe's Archiv f. Ophthal., Vol. XVI No. 2, p. 200, 1869.

A third test was made, and as it was the same as the second, the last glass was ordered—a simple cylinder (+ .25 D. cyl., 15°) for the left eye and a sphero-cylinder (— .50 D. + 3 D. cyl., 175°) right eye. In converting the cross-cylinder into a sphero-cylinder a minus sphere and a plus cylinder was ordered. This was a comparatively light-weight glass, and at the same time the cylinder corresponded with the cylinder in the opposite eye. A plus sphere and a minus cylinder in this case is not to be thought of, because the combined lens would be too heavy, and the cylinder would not correspond with the cylinder in the opposite eye.

In this case in the right eye the patient accepted a correction of all the (corneal) astigmatism indicated by the ophthalmometer, which means that there probably was no lenticular astigmatism. In the left eye there was no corneal astigmatism, but the patient accepted a weak plus cylinder against the rule.

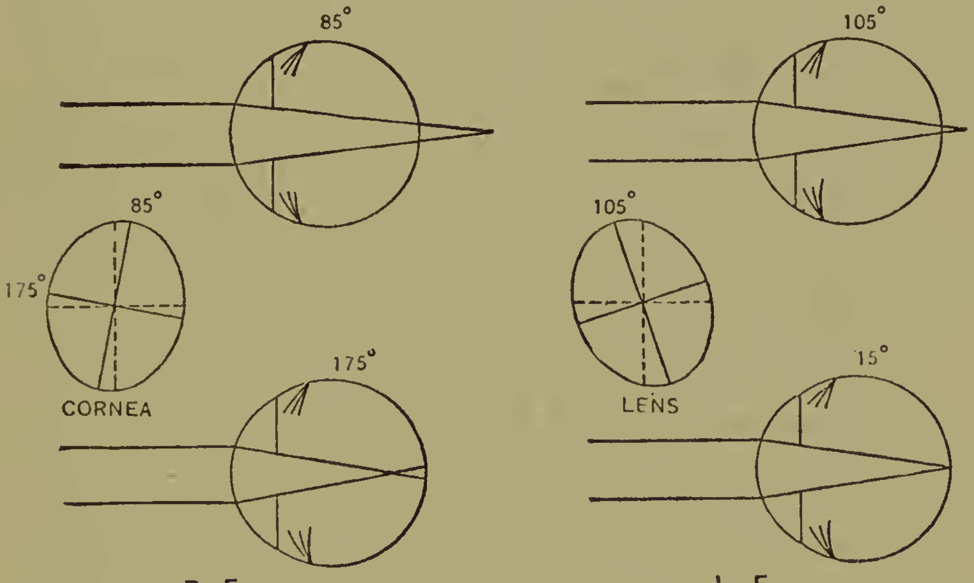


Fig. 103.

It took the patient between three and four weeks to become accustomed to the glasses, but after that time she wore them for many months with comfort and relief from asthenopia. At times she is nervous, but is much relieved in this respect.

Mixed astigmatism against the rule in each eye; Spasm of accommodation; Marked asthenopia; Relief with glasses.

J. F., aged 28, in good health, came on account of headaches and pains in the eyes. She has had more or less trouble with her eyes since childhood. She has a well-marked conjunctivitis.

Ophthalmometer. Astigmatism against the rule, 3 D., axis 155° + or 65° —, right eye; 2 D., axis 175° + or 85° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{100}$: $\frac{20}{50}$ W. + 1.50 D. cyl., 155° — 1.50 D. cyl., 65°.

$$\text{L. V.} = \frac{20}{50} : \frac{20}{30}\ \text{W.} + .75\ \text{D. cyl., } 175° - .50\ \text{D. cyl., } 85°.$$

Reads Jaeger No. 1 from 6 to 17 inches.

Ophthalmoscope. M. 1.50 D. at 150° and H. 1.50 D. at 60° right eye; M. 1 D. at 180° and H 1 D. at 90° left eye.

During the test (especially with the left eye) the patient one time accepted a certain glass, then refused it. Again, the vision at one moment would be very good; the next moment quite poor. Thus, spasm of accommodation was clearly present. Examination of the ocular muscles failed to show any insufficiencies. There was a well-marked conjunctivitis and this was treated for ten days, after which a second test was made.

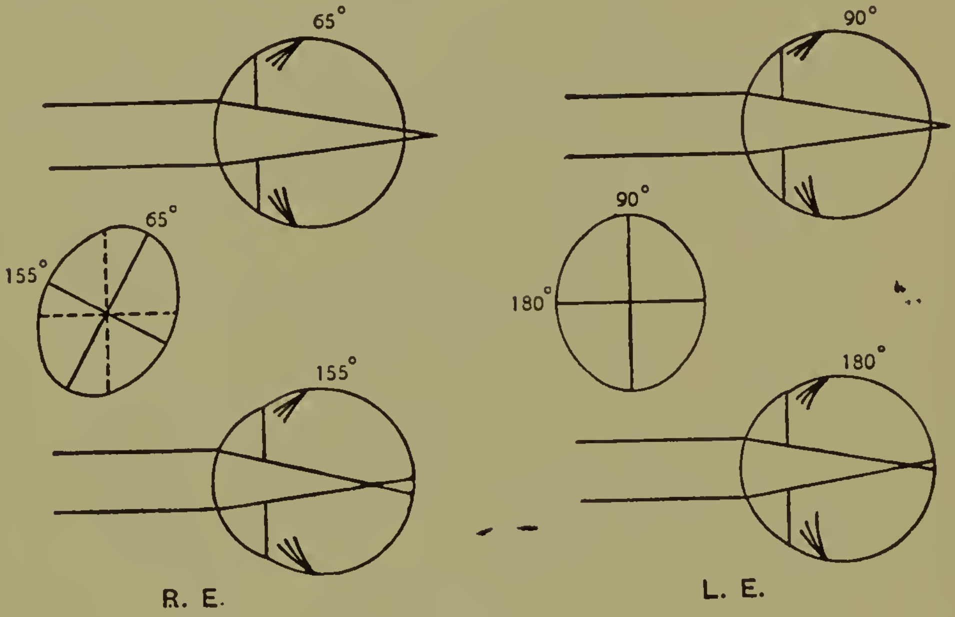


Fig. 104.

Second test: the ophthalmometer gave the same reading in the right eye as at the first test; and the same amount of astigmatism in the left eye as at first, but with the axes at exactly 180° and 90°.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{100} : \frac{20}{50}\ \text{W.} + 1.50\ \text{D. cyl., } 155° - 1.50\ \text{D. cyl., } 65°.$$

$$\text{L. V.} = \frac{20}{50} : \frac{20}{30}\ \text{W.} + 1.50\ \text{D. cyl., } 180° - .50\ \text{D. cyl., } 90°.$$

Ophthalmoscope. Showed about the same condition as at the first test.

A third test was given which agreed with the second, and the following glasses were ordered:

— 1.50 D. + 3 D. cyl., 155° right eye;
— .50 D. + 2 D. cyl., 180° left eye.

In the left eye this was a lighter glass than a plus sphere with a minus cylinder; while in the right eye it made no difference.

The glasses gave great satisfaction for four years.

Mixed astigmatism of small amount against the rule in each eye; Presbyopia; Asthenopia; Blepharitis; Relief with glasses.

H. C., aged 48, in good health, has been troubled with his eyes for five or six years when using them for close or prolonged work. The eyelids get red, also if he persists in using the eyes and, at times, headaches follow.

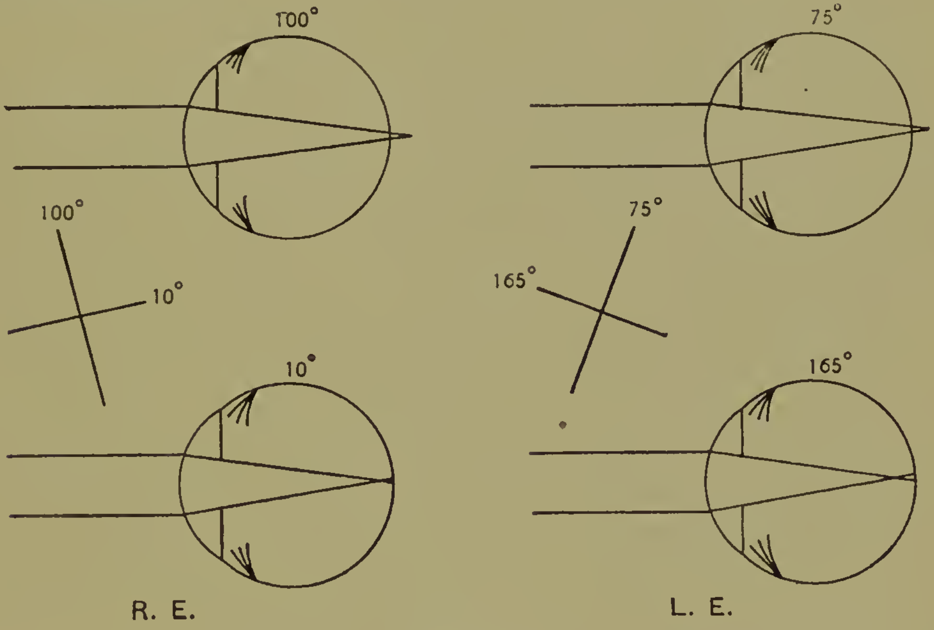


Fig. 105.

Ophthalmometer. Astigmatism against the rule, .50 D., axis 10° + or 100° —, right eye; .50 D., axis 165° + or 75° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{20}\ \text{W.} + .50\ \text{D. cyl., } 10° - .25\ \text{D. cyl., } 100°.$$

$$\text{L. V.} = \frac{20}{40} : \frac{20}{20}\ \text{W.} + .50\ \text{D. cyl., } 165° - .25\ \text{D. cyl., } 75°.$$

Ophthalmoscope. H. 50 D. in each eye. The myopic astigmatism was too small to estimate. The foci indicated by the two chief meridians, estimated from the accepted glasses, can be seen in Fig. 105.

Two days later a second test was made, which corresponded in every particular with the first. It will be noticed that the negative portion of the glasses accepted by the patient is of small amount, only .25 D. In the record of the case is the following note: "The — .25 D. cyl. when added to the + .50 D. cyl. increases the vision from $\frac{20}{30}$ — to $\frac{20}{20}$." Usually a .25 D. cylindrical glass does not improve vision so much, but in this case the astigmatism was against the rule and at an off axis, which may account for its marked effect in the improvement of vision.

The patient would not wear glasses for the distance, though they improved the vision very much. Incidentally it may be remarked here, that many, even intelligent, people are content with poor distant vision, and will not wear glasses at all, except for near work. Some, because they do not wish to be bothered with two pairs of glasses; some because of vanity, some for both reasons.

On account of his presbyopia (at 48 years of age) it was necessary to give this patient reading glasses. He was allowed + 1.75 D. for his presbyopia. After having converted his distance cross-cylinders into sphero-cylinders, — .25 D. + .75 D. cyl., 10°, right eye, and — 25. D. + .75 D. cyl., 165°, left eye, it was an easy matter algebraically to add the + 1.75 D. sphere to them which would give + 1.50 D. + .75 D. cyl., 10° right eye, + 1.50 D. + .75 D. cyl., 165° left eye.

The glasses were ordered, and were worn with satisfaction for five years and without change.

This case naturally brings up the question of transposition of formulæ in mixed astigmatism made necessary by presbyopia. The procedure is easy if the cross-cylinders are first converted into sphero-cylinders, as in the last case, then the presbyopic value added. Since this method of transposition has already been explained at length while considering myopia and myopic astigmatism, we shall not again consider the subject except to give one or two examples.

In the last case the change in the glasses made necessary by the presence of the 1.75 D. of presbyopia is made quite plain by a glance at Fig. 105. Here (right eye) the meridian at 100° is hypermetropic by .50 D., and the indicated focus is .50 D. back of the retina (+ .50 D. added to + 1.75 D. = + 2.25 D.); while the meridian at 10° is myopic by .25 D. with the focus to that extent in front of the retina, and the presbyopia of 1.75 D., for reading distance, would place the focus in this meridian but 1.50 D. back of the retina (— .25 D. added to + 1.75 D. = + 1.50 D.), that is, the myopia of .25 D. neutralizes that amount (.25 D.) of the presbyopia. It is quite evident, for reading purposes, that the refraction of the eye has been converted into a compound hypermetropic astigmatism, the meridian at 100° being 2.25 D. presbyopic, and that at 10°, 1.50 D. To correct this error a + 1.50 D. sphere, combined with + .75 D. cyl., 10°, is necessary. Like changes took place in the left eye, as will be seen by looking at Figs. 105 and 106.

The *amblyopia in most cases of mixed astigmatism* is the one great difficulty for many observers, and generally induces them to use a cycloplegic whether there are any other indications for its employment or not. In regard to amblyopia, a certain amount of it is to be looked for in most high degrees of astigmatism; consequently, we should not expect to bring vision up to normal in all cases. If the patient accepts the same glasses on two or three successive tests, and they correspond with the objective tests, we may give the glasses without hesitation.

In order to make doubly sure that we are not giving too weak plus or too strong minus cylinders in these cases, after we have tested each eye separately, we put the glasses on as accepted and uncover both eyes. With both eyes uncovered we increase the plus cylinder, .25 D. to see if the vision can be improved by the change, and we also diminish the minus cylinders .25 D. to find if vision can in the same way be improved, or if the patient reads as well with the weaker cylinder.

Another point to be insisted upon is that the test should be conducted methodically and quickly, and the patient kept not more than thirty minutes for any one test. Better to have the patient return two, three, or four times if necessary, than to worry him for an hour or two at a time in a vain attempt to get perfect vision. Because, first, as stated above, many times perfect vision is not to be had, whatever means are employed to develop it; second, if the test is very prolonged the patient grows tired and becomes confused in his replies, spasm of accommodation is incited, and the observer himself becomes discouraged. If after two tests, of not more than thirty minutes duration, the results do not approximately agree, and there is a tendency to, or an actual, spasm of accommodation, we should order a cycloplegic and work out the case with the retinoscope.

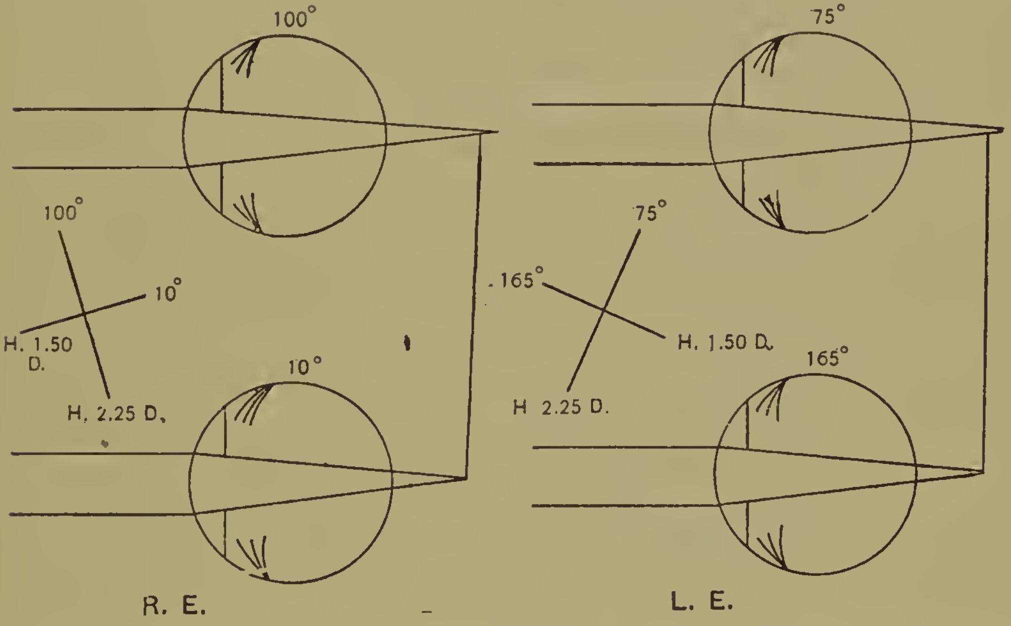


Fig. 106. Showing the Effect of a Presbyopia of 1.75 D. on the Near-point in the Case just reported. See Fig. 105 for the distance focus.

In all of these cases the routine method, so often referred to should be followed—to begin the test with weak plus lenses and gradually increase their strength until vision begins to be made worse, and then to try minus cylinders at right angles to the convex glass as long as they improve vision.

Mixed astigmatism, right eye; Compound myopic astigmatism, left eye.

M. J., aged 45, eyes give trouble for near work; sees specks in front of them.

Ophthalmometer: astigmatism with the rule, 6.50 D., axis 90° + or 180 —, right eye; astigmatism with the rule, 3. D., axis 105° + or 15 —, left eye.

Test cards and trial lenses.

R. V. = $\frac{10}{200}$: $\frac{20}{80}$ with — 4 D. = + 6 D. cyl., 90°.

L. V. = $\frac{20}{200}$: $\frac{20}{70}$ with — 2.50 D. = — 3 D. cyl., 15°.

Reads Jaeger No. 1 at 10 inches.

Ophthalmoscope shows M. 4 D. at 90°, and H. 2 D. at 180°, right eye; myopia 3 D. at 90, and 1.50 D. at 180, left eye. Posterior staphyloma each fundus, extending in a narrow strip almost to the macula and simulating a coloboma. Choroidal changes at each macula, were marked in left. Under homatropin the patient accepted — 4 D. = + 6 D. cyl., 90°, right eye; — 1.50 D. = — 3 cyl., 15°, left eye.

The ophthalmoscope and retinoscope confirmed the subjective test, and these glasses were ordered accordingly. For near work:

— 3 D. = + 6 D. cyl., 90°, R.;
—.50 D. = — 3 D. cyl., 15, L.

A year later, came again, as there was some difficulty in near work. Takes same distance glasses, but ordered for reading:

+ 6 cyl., 90°, right eye;
— 1.50 D. = + 1.50 D. cyl., 105°, left eye.

Mixed astigmatism against the rule, right eye; Mixed astigmatism with the rule, left eye; Intense pain in back of head most of the time; greatly improved with glasses.

H. A. R., aged 44, has had a dull pain on the right side and in the back of his head for two years past. This pain is intense at times and is never absent. General health fair, no history of syphilis. Wife has given birth to three healthy children, and there has been no miscarriages. Until lately the left ear discharged on and off since he was a child. Patient wears: Right, .50 D. ⊃ + 1.25 cyl. 180°; Left, .25 D. ⊃ + 1 cyl. 90°.

Ophthalmometer: astigmatism against the rule, .75 D. axis 180° + 90°, right eye; astigmatism with the rule, 1.25 D. axis 90° + 180° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{50}$ + : $\frac{20}{20}$ W. — .50 D. ⊃ + 1.25 cyl. 180°.

$$\text{L. V.} = \frac{20}{30} + : \frac{20}{20}\ \text{W.} - .25\ \text{D.} \supset + 1\ \text{cyl. } 90^\circ.$$

Patient reads Jaeger No. 1, 8 to 20 inches with + .75 D. added.
Muscles = ad. 17°, ab. 6° sur. R. & L = 2°.

Ophthalmoscope: H. .50 D. at 90° and M. .50 D. at 180°, right eye; Em. at 90° and H. .75 D. at 180°, left eye.

Because of the mixed astigmatism against the rule in one eye and with the rule in the other, a cycloplegic was used, although the patient was presbyopic.

Ophthalmometer: astigmatism against the rule, 1 D., axis 5° + or 95° —, right eye; astigmatism with the rule, 1.50 D., axis 90° + or 180° —, left. With *test lenses:*

$$\text{R. V.} = \frac{20}{70} : \frac{20}{20} +\ \text{W.} - .75\ \text{D.} = + 1.75\ \text{D. cyl. } 5^\circ.$$

$$\text{L. V.} = \frac{20}{40} + : \frac{20}{20} +\ \text{W.} - .37\ \text{D.} = + 1.37\ \text{D. cyl. } 90^\circ.$$

The ophthalmoscope and the retinoscope confirmed the above findings. A + .75 D. sphere was added as a bifocal and the glasses were ordered. They have been worn with comfort for five years, and with almost complete relief of pain in the head. When last examined the distance glasses were not changed but + 1.75 D. was added as a bifocal.

Mixed astigmatism with large amount of anterior lenticular astigmatism (1 D.) right; Compound hypermetropic astigmatism, left eye.

E. C., aged 21, complains of headaches and of burning in the eyes.

Ophthalmometer: astigmatism with the rule, 3 D., axis 95° + or 5° —, right eye; astigmatism with the rule, 1 D., axis 90° + or 100° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{70}\ \text{with} - 1.25\ \text{D.} = + 2.50\ \text{D. cyl., } 95^\circ.$$

$$\text{L. V.} = \frac{20}{15} : \frac{20}{15} +\ \text{with} + .50\ \text{D.} = + .37\ \text{D. cyl., } 105^\circ.$$

Ad. 7°, ab., 2°, sur. R. & L. 1°.

Ophthalmoscope shows M. 1.50 D. at 90°, and H. 1 D. at 180°, right eye; Em. at 90°, and H. .50 D. at 180°, left eye.

Ordered, after the usual tests, — 1.25 D. = + 2.50 cyl., 95°; + .50 D. = + .37 cyl., 105°.

Returned eight years later complaining of headaches.

Ophthalmometer: astigmatism with the rule, 3 D., axis 95° + or 5 —, right eye; astigmatism with the rule, .25 D., axis 105° + or 15 —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{40}\ \text{W.} + 5\ \text{cyl.},\ 95 = -\ 1.50\ \text{D.}$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{15}\ \text{W.} + 75.$$

Homonymous horizontal diplopia with red glass, which requires 2° prism, base out, to correct. Under homatropin: *Ophthalmometer:* in right eye corneal astigmatism with the rule, 3 D., axis 95° + or 5° —, lenticular astigmatism with the rule, ant. surface, .75 D., 95° + or 5° —; post. surface, negative. In the left corneal astigmatism with the rule, 25 D., 105° + or 15° —, lenticular astigmatism with the rule, ant. surface, negative, lenticular astigmatism against the rule, post. surface, 25 D., 15° + or 105° —.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{40}\ \text{W.} + 4\ \text{D. cyl.},\ 95^\circ \overset{\frown}{\smile} -\ 1\ \text{D.}$$

$$\text{L. V.} = \frac{20}{30} : \frac{20}{15}\ \text{W.} + 75.$$

Retinoscopy confirmed the subjective test and the above glasses were ordered.

CHAPTER XV.

ASTIGMATISM AFTER CATARACT EXTRACTION. EFFECTS OF THE TILTING AND DISPLACEMENT OF STRONG LENSES. ILLUSTRATIVE CASES.

As might be supposed, the aphakic or lensless eye, in which for refraction purposes only the corneal astigmatism has to be considered, is the ideal eye for the use of the ophthalmometer. Nevertheless, the nodal point is moved forward by the removal of the crystalline lens; hence the cylinder being combined, almost without exception, with a strong spherical glass (which must be worn one-half inch in front of the eye) the strength of the glass necessary for the correction of the astigmatism is rarely ever as great as that indicated by the ophthalmometer, even though the astigmatism is against the rule. The same law for reduction in strength holds in regard to prescribing spherical glasses after cataract extraction. For example, suppose the total amount of hypermetropia in an eye after cataract extraction is 11 D. Now, since there is no crystalline lens in such an eye, it might be expected that it would require a + 11 D. lens to correct the error, and, as a matter of fact, it would, could the glass be worn in contact with the cornea. But since the ordinary wearing distance of a glass from the eye is 12 to 14 mm., or about one-half inch from the corneal surface this interval perceptibly increases the strength of strong convex glasses; consequently a reduction in strength must be made. In the present supposed example of 11. D. hypermetropia, instead of the + 11 D. required to correct it, a much weaker glass, when placed at the usual one-half inch wearing distance in front of the eye, will suffice. To be exact, it would require a glass of only 3½ in. (the equivalent in inches of 11 D.) plus ½ in. (the ½ inch being the distance in front of the eye that the glass is worn), which equals a four inch focus glass; and a four inch focus equals 10 D., by which it is seen that one whole diopter should be deducted from the formula of the lens to be ordered for constant wear.

This increase of the power of a convex glass on account of its position in front of the eyes, obtains in all other instances as well as in aphakia, but the glasses in the former category are usually so weak that the slight displacement (one-half inch) does not make much difference in their refractive effect. There are, of course, exceptional cases where it does, but they are rare. In cataract cases the glasses must be very strong, unless the eye was strongly myopic before operation.

Let us consider another example where the patient is hypermetropic 5 D. before the operation, and after the operation has a hypermetropia of 16 D. It is evident that if a plus 16 D. (2½ in. focus) could be worn in contact with the cornea it would correct the 16 D. of hypermetropia; but, as it must be worn one-half inch in front of the eye, it must be reduced in strength. That is, it would require a glass of 2½ + ½, or 3 in. focus, which equals only 13 D., a decrease in strength of three diopters.

The discrepancy in the reading of the ophthalmometer and the cylindrical glass actually accepted by the patient after cataract extraction is not because of an error in the reading of the instrument, but is also to be ascribed chiefly to the reduction in strength that has to be made in strong cylinders on account of the one-half inch distance at which they must be worn in front of the eye, especially so when combined with strong spherical glasses. For example, if we have an astigmatism of 3 D., meridian 180°, and hypermetropia of 10 D., the correcting lens in the vertical meridian would be 13 D., and the horizontal meridian 10 D., if they could be worn in contact with the eye. But they are one-half inch in front of the eye, therefore 13 D. = 3 in. + ½ in. (in front of the eye) = 3½ in. or 11 D. for the vertical meridian. For the horizontal meridian, 10 D. = 4 in., + ½ in. = 4½ in. = 9 D. The difference between 11 D. and 9 D., the glasses which it respectively requires to correct the vertical and horizontal meridians, on account of their position in front of the eye, is only 2 D., and, therefore, it would take but 2 D. cyl. to correct the 3 D. of corneal astigmatism. Again, take 6 D. of astigmatism, 180° +, with 10 D. of H. The vertical meridian would require 16 D. (2½ in.) to correct it, if worn in contact with the eye; 2½ in. + ½ in. = 3 in. = 13 D., which glass the eye really accepts. The horizontal meridian would take 10 D. (4 in.); 4 + ½ = 4½ in. = 9 D. Now, 13 D. — 9 D. = 4 D., the cylinder, axis 180°, it takes to correct the 6 D. of corneal astigmatism.

Carl Weiland (*Archives of Ophthalm.*, Jan., 1893) has this to say: "Cases of aphakia are, therefore, the ideal field for keratometry, but owing to the high spheres usually necessary, there is a great difference between the correcting cylinder at 14 mm. from the eye and that in contact with the cornea, which latter, as we know, is given by Javal's instrument. The folloing table shows this at a glance, assuming that the spherical correction is + 10 D. for far, and + 14 D. for reading.

As. as shown by ophthalmometer	Spherical correction	Full correction for distance	As. as shown by the ophthalmometer	Spherical correction	Full correction for reading
+ 1	+ 10	+ 10 — .75 cyl.	+ 1	+ 14	+ 14 — .66 cyl.
— 1	+ 10	+ 10 + .73 cyl.	— 1	+ 14	+ 14 + .65 cyl.
— 2	+ 10	+ 10 + 1.45 cyl.	— 2	+ 14	+ 14 + 1.25 cyl.
+ 2	+ 10	+ 10 — 1.50 cyl.	+ 2	+ 14	+ 14 — 1.3 cyl.
— 3	+ 10	+ 10 + 2.1 cyl.	— 3	+ 14	+ 14 + 1.8 cyl.
— 4	+ 10	+ 10 + 2.8 cyl.	— 4	+ 14	+ 14 + 2.5 cyl.
— 5	+ 10	+ 10 + 3.50 cyl.	— 5	+ 14	+ 14 + 3.18 cyl.
— 6	+ 10	+ 10 + 4.1 cyl.	— 6	+ 14	+ 14 + 3.66 cyl.

"This shows conclusively the necessity of correcting in aphakia the keratomically determined cylinder for its position and for the coexisting axial condition, for even with a + 1 D. it amounts to .25 D. and more, while for an astigmatism of 6 D. against the rule, it amounts to almost 2.50 D. At the same time, we observe that in the same individual the cylinder may have to be reduced perceptibly for reading. We also find that the numbers obtained by the keratometer are always too high, no matter whether the astigmatism is with or against the rule.''

Weiland's position is correct as a rule, but we have more than once seen the patient accept exactly what the instrument indicated, and even more.

There is another source of error in high degrees of astigmatism—6 D. and over, and that is spherical aberration.

Thomas Reid (*Annals of Ophthalm.*, p. 456, July, 1897) calls attention to this point. He says: ''With Javal's instrument with an image of 3 mm., and with the portable ophthalmometer (Reid's) with an image of 2 mm., it is clear that from the spherical aberration the absolute size of the radius cannot be determined without reduction, as Leroy has done. Hence the necessity in these instruments of being adjusted to a spherical surface of known curvature, which at most expresses approximately the average curvature of the cornea. The results obtained by these instruments thus adjusted, although not theoretically perfect, will give the relative difference in degrees of corneal astigmatism not greater than 5 D. with sufficient accuracy for practical purposes.''

In regard to the limit of the measuring power of the Javal-Schiötz ophthalmometer, especially its capacity to determine the relative difference of the refractive power of the two priniepal meridians, even in very high degrees of astigmatism, the same restriction does not hold good in the Javal-Schiötz instrument as in Reid's, and for the following reason: In both instruments the size of the image remains constant (3 mm. in Javal's and 2 mm. in Reid's), but the size of the object varies.

In Reid's instrument, the object measured is through an iris diaphragm, which can be made to vary in size. Now, ''In this instrument, if we take the extremes of the index, 0 = 12 mm. and 0 = 16 mm., we find the corresponding diopters are 38.9 D. and 51.84 D.'' The difference between these two amounts, 51.84 — 38.9 equals 12.94, or about 13 D., the amount of the astigmatism (with the prism giving an image of 2 mm.) the instrument is capable of measuring.

In Javal's instrument, the object is the distance between the inner edge of the mires. When both of these mires move at once, as in the instrument with the double movable mires, the size of the object can be made to change from 10 cm. (100 mm.) to 40 cm. (400 mm.), the corresponding diopters to these numbers equal 20 D. and 80 D., respectively; and the difference between 80 D. and 20 D. equals 60 D., the amount of astigmatism the instrument is capable of measuring. Of course it could show such a great difference in only a relative way, because the spherical aberration would be so great in such a case that the measurement would not be accurate, but only approximate.

As for the astigmatism we meet with after cataract extraction, while it is very great in some cases shortly after the extraction (two to three weeks), amounting in rare instances to as much as 22 D., this, as a rule, rapidly diminishes, until within six weeks to two months it rarely amounts to more than 5 or 6 D., although in one case after extraction we have seen 12 D. of astigmatism remain permanently. So here, again, the ophthalmometer is within its range of practical and accurate work.

In a series of fifty cases E. O. Pfingst (*Arch. of Ophthal.*, Vol. XXV, pp. 333-334, 1896) found that the astigmatism, two weeks after operation, ranged from 1.75 D. with the rule to 22 D. against the rule; that this rapidly decreased for the next two to four weeks, then gradually diminished in amount for six months, after which, he found no further change. Our own experience is similar to that of Pfingst and others who have made investigations in this class of cases.

Complicated cases of cataract extraction are the ones that give rise to the largest amounts of astigmatism, incarceration of the iris in the whole length of the wound exerting the greatest influence on the shape of the cornea. Pfingst's casé of 22 D. occurred in a woman who fell from a stool at the end of the first week after the operation, and burst open the operative wound. In healing by second intention a grooved scar of the cornea remained which caused this very large amount of astigmatism.

In his series of fifty cases, Pfingst states that no patient accepted more than 6 D. cylinder, although one case had as much as 22 D. astigmatism shortly after the operation. In the case of 22 D. of astigmatism against the rule observed by the writer, the patient would not accept more than 8 D. cylinder at the first test, and, afterward, when the astigmatism had been reduced to 5 D., the patient accepted 4 D. cylinder, in conjunction with the sphere for distance, and 3.50 D. cylinder with the sphere for reading.

We have, however, seen one case where the patient accepted 16 D. cylinder twenty-seven days after the operation. It was a case where incarceration of the iris in the whole length of the wound had taken place; and still another case, in which 11.50 D. cylinder, combined with 4 D. sphere, was accepted for constant wear and with comfort. In the latter case, the wound reopened twice during the healing process, and left a corneal furrow. Both these cases are reported in full farther on in this section.

An important feature of the refraction in cataract operation *is the change in the meridian of the astigmatism.* We have found it to vary from five to thirty degrees in the first six weeks. This is accounted for by the healing process in the wound, the contraction of the scar, and, perhaps, to some extent, from the pressure of the lids during the healing. The meridians of the astigmatism finally became permanently placed, just as did the amount of the astigmatism. Because of the variations in the amount of the astigmatism and its meridians only temporary glasses should be given until the end of the second month after the operation, and it is safer to wait for five or six months before giving permanent glasses.

The correct adjustment of lenses after cataract extraction, especially where both eyes have been operated upon, is a most important matter. The adjustment for the distance or street glasses is quite different from that for near or reading glasses. While the distance glasses should not only be properly centered and should rest almost in the vertical plane, being very slightly tilted forward at the top to overcome spherical aberration, or a small amount of astigmatism (if present), reading glasses are to be decentered toward the nose, and should be worn at a lower plane or level than the distance glasses, in order to allow the patient to look through their centres. If this latter adjustment is not made the near glasses act as prisms, bases out, and cause diplopia for the near point in the horizontal plane; and, if not worn at a lower level than the distance glasses, act as prisms, bases up, causing diplopia in the vertical plane—the combined action giving a crossed vertical diplopia.

Holden (*Archives of Ophthalm.*, Jan., Vol. XX, pp. 1-25, 1891) has given a working formula for the decentering of lenses, as follows: $M = \frac{P \times 9}{D}$, in which M is the number of millimeters of decentering that is required to give a lens, D, of a certain power, to get the effect of a prism, P, of a certain number of degrees. As he says, "For the effect of any prism, multiply 8.7 mm. (practically 9) by the number of that prism, and for any lens divide this product by the number of diopters of the lens."

For example, we have a lens of 6 D. in each eye which we wish to decenter inwards, so as to act as prisms of 2°, bases in, $M = \frac{2 \times 9}{6} = 3$, the number of mm. of decentration required to give such a lens (6 D.) so as to act as a 2° prism. No displacement should be more than 7 mm. in each eye.

The practice of putting a distance glass in one eye-hole of a reversible spectacle frame and the reading glass in the other where but one eye has been operated upon, and causing the patient to reverse the frames when he wishes to change from distant to near vision, is an exceedingly bad one. With such frames it is impossible to give the correct adjustment, even with those that are reversed by turning on a vertical axis.

Spherical and chromatic aberration are other troublesome features inherent in the strong glasses necessary after cataract extraction, and must not be lost sight of. We wish to speak especially of spherical or monochromatic aberration, as it is sometimes called. See p. 23, Vol. 1 of this *Encyclopedia.*

William Harkness has shown that "with a pupil four mm. in diameter the normal cornea produces monochromatic aberration to the extent of $\frac{1}{33}$ (1.2 D.); and as there is no confusion of images in the normal eye, it seems probable that the crystalline lens exerts some compensating action. This suspicion is strengthened by the well-known fact that in aphakia the acuteness of vision is nearly always improved by giving a certain inclination to the powerful convex glasses which are necessary."

But the tilting of the strong convex glasses, necessary in cataract cases, serves not only to overcome spherical aberration but also for correcting a part or the whole of the astigmatism usually present after cataract extraction. Since this astigmatism is generally against the rule, that is, the vertical meridian, or one near it, is made flatter by the contraction of the scar, it can easily be corrected by rotating the strong spherical glass on its horizontal axis, or one near to it, the rotation being greater or less according to the astigmatism to be corrected.

John Green (*Trans. Am. Ophthal. Soc.,* Vol. V, pp. 690-717, 1888-90) gives a table (see below) showing the effect a certain number of degrees of tilting produces in various lenses. He says: "Every spherical lens is increased in power [by tipping] in all its meridians; the rate of increase and the actual increase being greatest in the vertical and the least in the horizontal meridian. A spherical lens is, therefore, also rendered astigmatic, and the excess of increase in power in the vertical meridian over that in the horizontal, for any given inclination, is the measure of the astigmatism.

"Every convex or concave toric or sphero-cylindrical lens is increased in power in all its meridians. When the two principal meridians of the lens lie in the vertical and in the horizontal plane, respectively, the rate of increase in power is greatest in the vertical and least in the horizontal meridian; and when the power of the untipped lens is greatest in the vertical meridian the actual increase is also greatest in the vertical meridian, and the astigmatism is also increased. When, on the other hand, the power of the untipped lens is greatest in the horizontal meridian, the astigmatism of the lens is at first diminished, and since the possible increase in power in the horizontal meridian is limited, there is always some value (of the angle of tipping or inclination) at which the astigmatism of the lens is reduced to zero, and beyond which the direction of the meridians of greatest and least refraction is reversed.

"In the case of a tipped plano-cylindrical (or other equivalent) lens, the greatest increase in power is in the meridian of the axis remaining at zero, the rate of increase, and also the actual increase in power, is greatest when the axis of the untipped lens is horizontal, and is least when the axis of the untipped lens is vertical."

The following table shows the relative increase in power of a lens of given strength when tipped a certain number of degrees, beginning at the vertical (where it is tipped no or zero degrees) and gradually increased to 90°. It is not practicable to tip any lens more than 20°.

Angle of tipping	Sphere	Cylinder or equivalent, axis 180°	Cylinder or equivalent, axis 90°
zero	1.	1.	0.
5	1.010	1.002	0.008
10	1.042	1.010	0.032
15	1.097	1.023	0.074
20	1.179	1.041	0.138
25	1.297	1.066	0.231
30	1.462	1.096	0.366
35	1.689	1.134	0.555
40	2.008	1.178	0.830
45	2.464	1.232	1.232
90	infinity	2.236	infinity

Ward A. Holden (*Archives of Ophthal.,* Vol. XX, pp. 1-25) gives a working table for the tilting of lenses, wherein he shows not only the relative increase in power of a spherical lens by being tilted a certain number of degrees, but the actual increase in power of the lenses most commonly used after cataract extraction.

Spherical, focus in inches	Tilting 10°	Tilting 15°	Tilting 20°
4½	1/180 +	1/52 —	1/40
4	1/160 +	1/52 +	1/26 —
3½	1/80 —	1/52 +	1/26 +
3¼	1/80 —	1/40 —	1/22 —
3	1/80 —	1/40 +	1/22 +
2¾	1/80 —	1/40 +	1/20 +
2½	1/80 +	1/32 —	1/18
2¼	1/80 +	1/32	1/16 +

For example, if a spherical glass of 2½ inch focus (16 D.), prescribed as a reading glass after cataract extraction, be tipped forward 10°, it increases its strength in the vertical meridian .50 D.; if tipped 15°, it increases its power in the vertical meridian 1.25 D.; and, if tipped 20°, its refractive value is greater in the vertical meridian 2.25 D. In each instance, however, its power would also slightly increase in the horizontal meridian. Moreover, if there was only a small amount of astigmatism against the rule, axis 180°, this could be easily corrected by tilting the strong plus spherical glass.

There is one disadvantage (as Holden points out) incidental to the tilting of strong spherical glasses. "The spherical lens tilted on a horizontal axis has the disadvantage that the refractive error is corrected only while the eye remains in a given horizontal plane. Suppose the upper edge of the glass tilted from the patient. Then, if he look through the lower part of the glass, the visual axis of the eye comes to form a smaller angle with the axis of the lens, and the effect of the tilting is correspondingly lost. If he look through the upper part of the glass, the visual axis is at a greater angle with the axis of the lens, and the refractive power is increased. For this reason, tilted spherical lenses are less adapted for distance than for reading."

Incidentally, it may again be said that myopic astigmatism with the rule, when associated with myopia of high degree, can be corrected by tilting the strong spherical glass on its horizontal axis. This follows from the fact that in compound myopic astigmatism with the rule, just as in hypermetropic astigmatism against the rule, the meridian of greatest error lies in the vertical plane, or one near it; and, by tilting the strong sphere on its horizontal axis it acts more strongly in the vertical plane than in the horizontal; and, in this way, small amounts of astigmatism can be corrected when associated with high degrees of spherical error. Except in very high degrees of myopia (10 to 18 D.), with astigmatism of small amount, 1 to 3 D., with the rule, this method should not be adopted; for, as pointed out by Donders (*Accommodation and Refraction of the Eye*, p. 511): "This means of correcting astigmatism is capable of application only when relatively strong spherical glasses are required to neutralize the ametropia; and then, too, a more perfect correction will be attainable by cylindrical curvature of one of the surfaces. Only in aphakia can we advantageously, in my opinion, in order to correct a certain degree of astigmatism, make use of an oblique position of the glasses. Almost always it appears that when we give a certain inclination to the strongly convex glass the acuteness of vision is improved, and the necessity of attending strictly to this in every case of aphakia is generally recognized." See, also, p. 1965, Vol. III, p. 4953, Vol. VII and p. 7212, Vol. X of this *Encyclopedia*.

ILLUSTRATIVE CASES

Astigmatism of large amount (6 D.) against the rule, two weeks after operation; Reduced to 1.50 D., two months after operation; Patient at that time accepted the total correction indicated by the ophthalmometer.

S. J. C., aged 55, in good health. Simple extraction of cataract, left eye. The operation was without complication, and the patient was discharged on the sixteenth day.

Ophthalmometer. Sixteenth day, astigmatism against the rule, 6 D., axis 150°; after one month, 4 D., axis 150°; two and one-half months, 1.50 D., axis 150°.

Test cards and trial lenses. Sixteenth day.

$$\text{L. V.} = \frac{20}{50} \text{ with } + 10 \text{ D.} + 4 \text{ D. cyl., } 150^\circ.$$

Ophthalmoscope and oblique illumination showed a clear pupil. Two and one-half months after the operation, the ophthalmometer showed astigmatism of only 1.50 D., which the patient accepted in full:

$$\text{L. V.} = \frac{20}{15} \text{ W.} + 13 \text{ D.} + 1.50 \text{ D. cyl., } 150^\circ.$$

Read Jaeger No. 1 at 12 inches with + 17 D. + 1 D. cyl., 150°. Both the distance and reading glasses were ordered, which she wore with comfort for two and one-half years, and maintained the same acute vision.

It will be noticed in this case that the cylinder (of the reading glass) had to be reduced in strength.

Astigmatism of large amount (15 D.) against the rule three weeks after the operation; Reduced to 13 D. after two months, and to 12 D. only after a year and a half, leaving 12 D. astigmatism permanently; Patient accepted + 11.50 D. cylinder combined with 4 sphere; Axis of astigmatism did not change in the first two months, but made a change of 15° after eighteen months.

J. G., aged 77, in good health, had a simple extraction of cataract from the left eye. The operation was without mishap, but during healing the wound gaped twice, so when finally healed there was a deeply grooved sclerocorneal scar at the site of incision. Pupil circular and central, but at time the patient was discharged (twenty-first day) there was a membrane in it. One month after the operation a needling was done, leaving a clear pupil.

Ophthalmometer. After three weeks, astigmatism against the rule, 15 D., axis 165°; two months, 13 D., axis 165°; eighteen months, 12 D., axis 180°.

The *ophthalmoscope* showed an opening in the membrane in the pupil 3 mm. by 2 mm.; pupil central and circular.

Test cards and trial lenses. One month.

$$\text{L. V.} = \frac{20}{200} \text{ with } + 3 \text{ D.} + 12 \text{ D. cyl., } 165^\circ.$$

Two months.

$$\text{L. V.} = \frac{20}{70} \text{ with } + 4 \text{ D.} + 11.50 \text{ D. cyl., } 165^\circ.$$

On account of the large amount of astigmatism, due to the grooved wound, distance glasses only were ordered: + 4 D. + 11.50 D. cyl., 165°. The patient accepted the glasses and returned after sixteen months. The ophthalmometer then showed the astigmatism to be 12 D., axis 180°, instead of 165°, as at first. There was still a decided groove at the upper margin of the cornea.

Test cards and trial lenses.

$$\text{L. V.} = \frac{20}{30} \text{ W. } + 6.50 \text{ D.} + 10.50 \text{ D. cyl., } 180^\circ.$$

Reads Jaeger No. 1 at 9 inches, with + 11 D. + 10 D. cyl., 180°. Both these distance and reading glasses were ordered.

It will be seen that distant vision was increased with this last glass to $\frac{20}{30}$, while $\frac{20}{70}$ was the best vision obtained two months after the operation. Furthermore, the axis of the glass had changed to 180°.

The change in the meridians of the astigmatism did not take place until two years after the operation. This we have seen in but one other case so long after an extraction. It will be noticed, too, that the strength of the spherical glass had to be increased as the strength of the cylinder was diminished, a point already noted above in other cases.

An 11.50 D. cylinder is the strongest cylindrical cataract glass that we have ever seen worn; but in this case it gave the best vision, and we did not hesitate to order it. Even eighteen months after the operation, + 10.50 D. cylinder for distance, and + 10 D. cylinder for reading, in combination with spheres, had to be ordered.

Astigmatism of high degree (22 D.) against the rule two weeks after operation; 5 D. against the rule one year after operation, at which point it remained stationary; Change in axis of 10° during healing.

A. F., aged 55, in good health, had a simple extraction of cataract from the left eye. The wound quickly healed, but on the seventh day the patient fell from a chair on which she was sitting and burst the wound open. She was discharged on the seventeenth day; pupil central and circular.

Ophthalmometer. Astigmatism against the rule, 22 D., axis 180°; in one month, 12 D. axis 170°; five months, 5 D., axis 170°; one year, 5 D., axis 170°.

Test cards and trial lenses. After seventeen days.

$$\text{L. V.} = \frac{20}{100}\ \text{W.} + 8\ \text{D.} + 8\ \text{D. cyl., } 180°.$$

One month.

$$\text{L. V.} = \frac{20}{40}\ \text{W.} + 10\ \text{D.} + 8\ \text{D. cyl., } 170°.$$

Five months.

$$\text{L. V.} = \frac{20}{20}\ \text{W.} + 12\ \text{D.} + 3.50\ \text{D. cyl., } 170°.$$

Jaeger No. 1 at 12 in., with + 16 D. + 3 D. cyl., 170°.

Ordered both the indicated distance and reading glasses. This patient was seen one year after the extraction, and the astigmatism had not changed from the finding at the fifth month.

Twenty-two diopters is the highest amount of astigmatism after a cataract extraction we have ever seen. Although the ophthalmometer registered this very large amount of astigmatism, at no time would the patient accept more than an 8 D. cyl.

Astigmatism (4.50 D.) with the rule three and one-half weeks after operation; Changed to 1.50 D. against the rule after three years; Remained thus at the end of five years from operation; Case remarkable for acuteness of vision obtained (20/10) and for accommodative power after the extraction of the lens.

E. C., aged 42, in good health, had extraction, with iridectomy, of a "black" cataract, from the right eye. The wound did not heal completely for a week. Only a very shallow anterior chamber formed, but at the end of the week the wound closed completely and the eye recovered with the remarkable vision of $\frac{20}{10}$ (Snellen).

At the end of three months it was discovered that he had a considerable range of accommodation in the eye. The case was reported at length in the *Manhattan Eye and Ear Hosp. Reports,* Jan., 1895. His vision just before the operation was:

$$\text{R. V.} = \frac{20}{70}\ ;\ \text{L. V.} = \frac{20}{40}.$$

Jaeger No. 12 at 10 inches right eye, and No. 9 at 10 inches left eye. Though this vision was so good by the Snellen test, he could not recognize friends or members of his own family on the street, had not worked for five years, and insisted on the operation being done.

Ophthalmometer. Before the operation, astigmatism with the rule, .50 D., axis 90° + or 180° — in each eye; three and one-half weeks after the operation, astigmatism with the rule, 4.50 D., axis 90°; three months after the operation no astigmatism whatever; three years, astigmatism against the rule, 1.50 D., axis 5°, and five years after, exactly the same as at three years, both as to the amount and meridians of the astigmatism.

Test cards and trial lenses. Three and one-half weeks,

$$\text{R. V.} = \frac{20}{50}\ \text{W.} + 9\ \text{D.} + 3.50\ \text{D. cyl., } 90^\circ.$$

Three months,

$$\text{R. V.} = \frac{20}{10}\ \text{W.} + 11.50\ \text{D.}$$

Jaeger No. 1 at 12 to 15 inches, with + 15.50 D.

The patient, however, discarded the reading glasses ordered and used the distance glasses for all purposes. With this distance glass (11.50 D.) he read $\frac{20}{10}$ — (Snellen), and Jaeger No. 1 from 8 to 22½ inches, without changing the position of the glass at all on his nose. Three years and four months after the operation the ophthalmometer showed astigmatism against the rule.

$$\text{R. V.} + \frac{20}{10} — \text{W.} + 10.50\ \text{D.} + 1.50\ \text{D. cyl., } 5^\circ,\ \text{and}$$

Jaeger No. 1, *with the same glass,* from 8½ to 22½ inches.

When last examined the astigmatism was the same as at the end of three years, the patient had vision $\frac{20}{15}$ and still retained the power of accommodation. The ophthalmoscope and oblique illumination showed the fundus of the eye normal and the media perfectly clear. The pupil was oval (from iridectomy above) but free from membrane, except a very narrow strip at the margin.

Astigmatism 6 D., axis 45°; Section was made directly above for the extraction, but the nasal side of the wound (left eye) broke open during a needling on the twelfth day; Ultimate vision 20/20.

E. B., aged 53, good health, had a simple extraction of cataract from the left eye. No accident during the operation, and the eye did well. Twelve days later, when the operator attempted to perform a needling, the patient squeezed the eye violently and opened the wound on the nasal side. Within four days the wound had healed again, but no further attempt to needle was made until five months later, when a successful needling was performed.

Ophthalmometer. Seventeenth day, astigmatism with the rule, 6 D., axis 45°; five months, 1.50 D., axis 45°.

Test cards and trial lenses (seventeenth day)

$$\text{L. V.} = \frac{20}{100} \text{ with } + 9 \text{ D.} + 6 \text{ D. cyl., } 45^\circ.$$

The ophthalmoscope and oblique illumination show a membrane in the pupil.

Five months, and after needling,

$$\text{L. V.} = \frac{20}{20} \text{ W. } + 13 \text{ D.} + .50 \text{ D. cyl., } 45^\circ.$$

Reads Jaeger No. 1 at 10 inches, with + 18 D. sphere, without any cylinder. Both the reading and distance glasses were ordered.

As a rule, after cataract extraction, the axis of the correcting cylinder is accepted and worn horizontally with the base of the section; but, exceptionally, it is preferred with its axis at right angles to the direction of the wound, as in the few cases where the astigmatism is with the rule. The usual position of the corneal section in cataract operations being in the upper segment the astigmatism that follows is commonly against the rule, and requires a correcting cylinder with its axis at or near 180°, or horizontal and in the direction of the puncture and counter puncture. The exceptions to this general rule are: first, where there has been a high degree of myopia, and the astigmatism is against the rule when the axis of the cylinder must be worn at or near 90°, or at right angles to the base of the corneal section; second, where the astigmatism is with the rule after extraction, in which instance the cylinder must be worn at or near 90°, or at right angles to the base of the corneal section.

In the case just reported when the patient squeezed the eye violently and the wound opened, the cicatrix that formed caused the meridians of greatest and weakest curvature to lie at 45° and 135° respectively, as shown by the ophthalmometer.

Refraction of high myopes after cataract extraction.

Percival (*Archives of Ophthalm.*, Vol. XXVI, pp. 1-4) says some operators have expressed great surprise at the marked change in the refraction in *high myopia* after cataract extraction, when, as a matter of fact, they should expect it. Helmholtz, Donders and others have shown that an axial myopia of between 25 D. and 26 D. may be entirely corrected by simply extracting the lens.

Since it requires about + 11 D. to correct the emmetropic eye after cataract extraction, it would naturally be supposed that a myopia of 26 D., after cataract extraction, would require a lens representing the difference between — 26 D. and + 11 D. (—15 D.) to correct it for the distance. But such is not the case, and Percival, after giving a table of such cases, remarks that the change in refraction due to the operation increases with the previous degree of axial myopia. In other words, the higher the degree of myopia before the operation, the greater the influence proportionally will the extraction of the cataract have on the total refraction. We reproduce, in part, his table.

Antero-posterior dimension, or optic axis	Power of glass to correct before operation	Power of glass to correct after extraction	Change in refraction
23 mm.	— .50 D.	+ 11.2 D.	11.7 D.
26 mm.	— 9.9 D.	+ 7. D.	16.9 D.
29 mm.	— 19.2 D.	+ 2.9 D.	22.1 D.
32 mm.	— 28.50 D.	— 1.25 D.	27.3 D.

Operators of experience claim that by the removal of the lens in excessive myopia the visual acuity is increased through the enlargement of the retinal images, that the strain of convergence is lessened and that congestion of the fundus is relieved. Favorable results after removal of the crystalline lens in high myopia have been published but we should not forget the *contraindications and dangers* of the operation.

These are chiefly, (1) degenerative changes in the choroid or retina, especially if in or near the macula; (2) vitreous opacities, which usually indicate pathologic alterations in the blood vessels; (3) marked corneal scars; (4) myopia of less than 12 D.; (5) other conditions that contraindicate extraction of senile cataract, as trachoma, detachment of the retina, advanced age, etc.

The chief dangers of the operation itself are: (1) intraocular hemorrhage and (2) detachment of the retina.

When we consider that one of the contraindications of the operation is a myopia of less than 12 D., and another, and the most serious one, degenerative changes in the choroid and retina, and remember, also, how few eyes with myopia of more than 12 D., present healthy fundi, it will be apparent how few eyes one sees suited to this operation. If we were to seek only ideal conditions for the operation and to look for about 2 D. of myopia after the operation (so that the patient would not need a glass for the near point) the eye must have had about 30 D. of myopia before the operation. Now 30 D. of myopia is so rare as hardly ever to be met with, and when it is encountered degenerative changes in the fundus are almost certain to be present and to contraindicate operative procedure. Even theoretically to obtain emmetropia after the operation a myopia of 25 or 26 D. is necessary before the operation. However, Von Hippel and others have found that emmetropia may be obtained by extracting the lens (discission) in myopia of only 15 D.; and in myopia of 18 to 20 D., it is obtained in about 25 per cent. of the cases. See **Myopia**, as well as p. 8274, Vol. XI of this *Encyclopedia.*

Further observations on the operative treatment of high degrees of myopia.

[In addition to what has been said here and elsewhere in the pages of this *Encyclopedia* on the above subject Peter A. Callan (Wood's *System of Ophthalmic Operations,* Vol. II, p. 1309) has made an important contribution which is largely reprinted as follows:

Surgeons of the eighteenth century were aware of the visual advantage gained by myopes after the successful removal of cataract. Boerhaave (*De morbis oculorum,* Göttingen, 1708, page 231) in 1708 was the first to publish his observations and called attention to the fact that myopes after the removal of the cataract could see without the aid of glasses. Moreover, Woolhouse (*Dissertations savantes et critiques sur la cataract*) in 1717, likewise commented on the fact that myopes after the removal of the opaque lens could see without the aid of glasses. Higgs in 1755 noticed that depression of the cataractous lens cured myopia. Deshais-Gendron in 1770 and Janin in 1772 both called attention to the benefits accruing to myopes after the removal of cataract, as they were able to dispense with the use of glasses for far and near.

The Abbe Desmonceaux (*Traité des maladies des yeux et des* *oreilles,* 1786, Vol. II, p. 140) was the first to advocate the removal of the clear lens for myopia. He never performed the operation because, as he naively puts it, being a clergyman, it would not have been consistent; furthermore he would not have the courage to do it. Consequently he referred the cases to expert surgeons and especially mentions Baron Wenzel who had performed many of these operations at his suggestion. Wenzel, however, makes no mention in his writings of having removed the clear lens in high myopia. During the latter part of the eighteenth to the early part of the nineteenth centuries many surgeons referred to the subject of operative interference in high myopia, namely: Richter, Gleize, Beer, Andreas, Weller, Desmoulins, Demours, and Benedikt, but there is no evidence that any one of these had operated on the clear lens. The subject was discussed from a theoretical standpoint, the writers expatiating on the risk and danger likely to follow such an operation.

Mackenzie (*Diseases of the Eye*, London, 1830, page 528) in 1830 refers to Sir William Adams as having removed the clear lens for the relief of conical cornea. Adams had operated on a woman seventy years of age, suffering from conical cornea and cataract, and was gratified to find that the patient could see more distinctly without glasses than is usually the case. The experience thus gained determined him to remove the clear lens in conical cornea at the first opportunity. The following year a suitable case presented in the person of a domestic; a young woman, on account of conical cornea, was so blind that she could not continue her employment. She could walk without a guide and could see at a distance of three or four feet, but had entirely lost the power of seeing small objects or reading. He performed discission on one eye, and the patient returned to the country before the eye had entirely recovered from the operation. It was almost a year before she was seen again by Adams, who found that she could read the finest type, without a glass, at a distance of ten to twelve inches from the eye. The vision was improved for near, with weak convex lenses, but distant vision was best without glasses.

Radius in 1836, advised the removal by discission of the clear lens for the relief of high myopia, but there is no evidence that he performed the operation. In fact, the subject is not even mentioned or referred to in books on ophthalmology until the Heidelberg Congress in 1858.

Adolph Weber, of Darmstadt, reported a successful case and Mooren advocated operating in high myopia.

Von Graefe and Donders, however, deprecated the idea, referring to the great risk involved, besides the loss of accommodation. Some six years later, Donders expressed himself as follows in regard to the operation: "But I need not say that such a momentous undertaking is doubly dangerous when a myopic eye and a transparent lens are concerned. To expect that even in the most favorable case, any real advantage is to be expected would exhibit culpable rashness. Not only would the staphyloma posticum continue equally threatening, but it would sacrifice the accommodation, a disadvantage which somewhat larger images obtained by neutralizing glasses would not counterbalance."

Two weeks after the adjournment of the Heidelberg Congress, Mooren operated on the clear lens of a young man, thirty years of age, for high myopia with phthisis bulbi as the outcome. With the exception of a few isolated operations, the matter remained in abeyance until 1888, when Fukala reported the results of his operations in fourteen cases of high myopia in young subjects from whom he had removed the clear lens.

The report was a revelation to the medical profession. For the first time the question ceased to be theoretical and abstract and became practical and concrete. It required no little moral courage to rehabilitate an operation frowned upon by the founders of modern ophthalmology.

Fukala's experience (*Wiener Klin. Wochenschr.*, Nov. 8, 1889, p. 888) might have been that of Weber's, thirty years before, had not the era of asepsis been introduced in the meanwhile.

As an appendix to a translation of one of Fukala's papers is the following note of a case operated on by a Chicago colleague: In 1880, an Irishman, æt. 35, a bookkeeper, presented himself for treatment. He had a myopia of ½ (20 D.), his far point being 2″ from the cornea. The right lens was extracted by the flap operation without iridectomy and came away entire. With minus 1/8 or 1/7 (minus 5 or minus 6 D.) he had, three months after the operation, vision of 20/xxiv minus and was able to do bookkeeping. The left lens was not disturbed.

Vacher (*Bulletins et Mem. de la Soc. franc d'ophtal.*, 1890, p. 197) about the same time, without the knowledge of Fukala's work, had extracted the clear lens for high myopia with the avowed object of preventing retinal detachment and progressive choroidal degeneration.

Arguments for and against the removal of the clear lens in high myopia. High myopia is a great handicap entailing a train of physical discomforts and disabilities that disqualify persons for and exclude them from many occupations where good vision is a *sine qua non.* The strong convergence necessary to see distinctly at a very near point is often accompanied by spasm of the accommodation causing vascular disturbances and choroidal stretching leading to degenerative changes in the fundus oculi.

The full correction of high myopia is rarely worn with comfort and often the attempt is likely to be followed by nausea, headaches, dizziness and general malaise. Strong concave lenses act as prisms, reduce the size of objects and lead to false estimates of distances.

The removal of the clear lens in high myopia is a rational procedure, resulting in great benefit in suitable cases. On the other hand, indiscriminate operating leads to disastrous results and tends to discredit an otherwise beneficial operation. The vision improves after the operation in varying amounts from 1/6th to 1/3d of the normal. The retinal images and fields of vision are enlarged. Distant vision is obtained with or without strong lenses (at most a weak convex or concave glass), while near vision generally requires a comparatively low power convex glass. The excessive convergence, with its spasm of accommodation, is no longer necessary. The range of accommodation is quite sufficient, often amounting to several diopters. No patient with high myopia, after the successful removal of a clear lens, would willingly resume the former *status quo.*

The operation should be confined to high degrees of myopia, as it is in such cases that the greatest benefit is likely to accrue. Lower degrees mean, after removal of the lens, separate, strong, convex lenses for far and near vision.

There is no absolutely accurate means of determining what the resulting refraction is going to be after the removal of the lens. Formulæ to determine it have been published by Badal, Ostwalt, Eperon, Hirschberg, Stadfelt, and Pflüger that give only approximate results.

An emmetrope (i. e., a subject with a slight amount of hyperopia), after cataract extraction, sees distant objects with a + 10 D. and a cylinder of greater or less amount. However, a myope of 10 D. does not become emmetropic after the removal of the lens. Eyes with an equal amount of myopia prior to operation, have shown differences as high as 10 D. after the removal of the lenses.

The refractive index of the lenses of emmetropia, as shown by Donders and Becker, may vary from 2 to 3 D. Besides the axial length of the eye-ball (which is the chief factor in the different refractive types) the radius of the cornea, the depth of the anterior chamber, as well as the shape, size and density of the lens are modifying conditions to be considered.

Donders found the average radius of the cornea in the three refractive types as follows: Hyperopia, 7.96 mm.; emmetropia, 7.85 mm.; myopia, 7.87 mm. Mauthner found the following: Hyperopia, 7.623 mm.; emmetropia, 7.708 mm.; myopia, 7.584 mm. Von Reuss reported these findings: Hyperopia, 7.739 mm.; emmetropia, 7.44 mm.; myopia, 7.52 mm.

According to Donders' and Von Reuss' tables, the emmetropic eye has the shortest corneal radius, while Mauthner found first, the myopic eye, with the hyperopic next in order. In other words, the measurements by the ophthalmometer of the cornea in the three refractive types vary but little from each other. Strictly speaking, there are only two refractive conditions, hyperopia and myopia, inasmuch as the emmetropic eye means a small amount of hyperopia or hyperopic astigmatism.

In measuring the cornea with the ophthalmometer, the eye should be in a condition of absolute rest (with paralysis of the accommodation) and a passive state of the extrinsic ocular muscles. [I do not agree with this statement.—A. E. D.]

Indications for operation in high myopia. The social status of the patient, the ability to continue employment, and the earning capacity are factors to be considered. If the vision is so poor that work at fourteen inches is no longer possible, or if no remunerative employment can be obtained, so that the individual becomes dependent on relatives or the State for support, the operation is urgently called for. Besides, there are occupations where the wearing of glasses is almost prohibitory (as for cooks, coachmen, sailors) where vapor, rain or prejudice militates against their use.

When the myopia is so high that no lens gives satisfactory results or where distant vision is little better than one-tenth of normal; and if the macula lutea be intact with fair vision for near, the operation is justifiable. As to the amount of myopia likely to be benefited by an operation, it varies according to the ideas of different surgeons. Some fix 12 D. as the lowest limit. The chief objection to such a small amount is a resulting high degree of hyperopia in the aphakic eye, requiring strong convex lenses, both for far and near. It appears to some that 16 D. is the lowest amount and the one most likely to give the best results, viz., a weak convex lens for near work and no glass for the distance.

The patient should be made fully aware of the risk to be run in the operation; that the eye-sight may be lost as a direct result of the attempt to remove his lens. When a patient is blind from cataract, there is everything to be gained by an operation, and if unsuccessful, the eye is still blind. Not so, however, in high myopia, as the operation may lead to the loss of a seeing eye.

Contra-indications. Where the patient has only one eye, or where in the fellow eye there is a detached retina, it would not be wise to risk the loss of the remaining sound eye.

Destructive changes at the macula lutea, with defective near vision, should be excluded. Hemorrhages into the vitreous, choroid, or retina are contra-indications, but the ordinary chorio-retinal changes of high myopia even when they involve the macula lutea but still leave the patient with fair vision, do not bar the operation.

Dacryocystitis, trachoma in the acute stage, or inflammation of the eye-lids with purulent secretion, ozena, or diseases of the nasal sinuses ,are contra-indications, as are a hazy cornea or media that would militate against the final results. General constitutional diseases interfere with the good results in proportion as the entire system is enfeebled.

Although three decades have almost elapsed since Fukala's first report, there are still some moot points yet to be definitely settled, viz., the ultimate effects of the removal of the lens in regard to, first, axial length; second, effect on the fundus changes; third retinal detachment.

Mooren, as a prophylactic measure removed the clear lenses from young persons with (progressive) myopia, ranging from 2 to 5 D., with unsatisfactory results. The axial length increased and the fundus changes continued. Most other operators found that the antero-posterior axis remains unchanged, or, at most, there is very little increase in length. At present, it is not possible to state positively that the removal of the lens always stops the increase of the axial length, or brings the fundus changes to a standstill. However, judging by the experience of the majority, the axial length does not increase, and if it does, it is only exceptionally; and the same holds good of the fundus changes.

Retinal detachment occurs not infrequently in high myopia, irrespective of the removal of the lens, and the question naturally arises, how much of a factor is the operation in its causation? Can it be held responsible, when we know that retinal detachment and choroidal hemorrhage rarely follow cataract extraction in ordinary cases of emmetropia and high myopia?

The following table statistics dealing with this subject are quoted from K. Bjerke's (*Zeitschr. für Augenheilk.*, Bd. VIII, 1902, p. 137-175) paper:

Surgeon	Operation	Detachment of the retina, per cent.
Schweigger	Discission and linear extraction	7 in 50 cases, 14
Thier	ditto	4 in 50 cases, 8
Frölich	Discission through the entire lens and linear extraction	4 in 56 cases, 7
Von Hippel	Discission and linear extraction	10 in 184 cases, 5.4
Schreiber	ditto	1 in 19 cases, 5.2
Silex	ditto	1 in 20 cases, 5
Rogmann	Discission and suction	1 in 20 cases, 5
Sattler	Discission and extraction	4 in 85 cases, 4.7
Sattler	Primary extraction	1 in 30 cases, 3
Darier	ditto	4 in 142 cases, 2.8
Blessig	Discission and extraction	1 in 50 cases, 2
Pflüger	ditto	1 in 100 cases, 1
Vacher	Primary extraction	0 in 61 cases, 0
Haab	Discission and extraction	0 in 50 cases, 0
Gelpke	ditto	0 in 50 cases, 0
Schmidt-Rimpler	ditto	0 in 12 cases, 0
Schleich	ditto	0 in 60 cases, 0
Völckers	ditto	0 in 17 cases, 0
Hirschberg	ditto	0 in 20 cases, 0
Silvestre	ditto	0 in 10 cases, 0
Röhmer	ditto	0 in 8 cases, 0
Maxwin	ditto	0 in 10 cases, 0
Logetschenkow	ditto	0 in 40 cases, 0
Hertzog de Grandleur	ditto	0 in 20 cases, 0
Batten	ditto	0 in 6 cases, 0
Bjerke	ditto	0 in 6 cases, 0

Referring to the foregoing table, 1,176 cases were operated on by twenty-five surgeons. The procedure employed to remove the clear lens by eight surgeons in 262 cases is not specified; 914 cases were operated upon by seventeen surgeons by the following methods: 9 surgeons operated by discission and extraction in 474 cases; 5 surgeons operated by discission and linear extraction in 329 cases; 1 surgeon operated by discission and suction in 20 cases; 10 surgeons operated by primary extraction in 91 cases.

The greatest number of operations were discission and extraction. Next in order comes discission with linear extraction; primary extraction without discission; and the lowest number by discission and suction. In not a single instance was discission solely depended upon to remove the clear lens.

Six surgeons (method specified) had no retinal detachment. Six surgeons in 250 cases (method specified) had no retinal detachment.

Eight surgeons in 262 cases (no method specified) had 2.8 per cent. of loss of the eye.

If we consider the entire 1,176 patients, operated on by twenty-five surgeons, the proportion of retinal detachment was about 4.83 per cent.

Frölich (*Archiv. für Augenheil,* Vol. 35, 1897, p. 267) collected the statistics of retinal detachment in myopes over 10 D. and compared those not operated on with those operated on for high myopia. He found 3.3 per cent. of the latter with retinal detachment, against 2.2 per cent. retinal detachment in patients not operated on.

Von Hippel found 6.7 per cent. myopes over 10 D., who had not been operated on as compared with 5.4 per cent. in those who had one or both lenses removed.

Retinal detachment (it would appear from the experience of these surgeons) occurs somewhat more frequently in eyes, from which the transparent lens has been removed, but the percentage is not large, when compared with that which takes place in high myopia. The different results obtained by various surgeons suggest that this accident results not so much from a particular form of operation as in the carrying out of the technic.

In high grade myopia should one or both eyes be operated on? Advocates of the need of binocular vision are outspoken in favor of removing both lenses. To the writer's mind, it is a question for the patient to decide; when a sufficient period of time has elapsed after the first operation, let him fully determine what he needs. The surgeon should not influence the patient on purely theoretical grounds. Besides the risk of a double operation, the loss of time must be considered. As the result of some experience in these matters, one feels that a decision should lie wholly in the hands of those most interested in the result. A patient blind from cataract in submitting to an operation followed by untoward result is in a totally different position from one who loses a seeing eye as a result of an operative procedure.

The operation of election for high degrees of myopia. There are three operative methods open to the surgeon: First, *discission;* second, *discission with linear extraction;* and third, *primary extraction.*

The easiest and safest procedure for the removal of the clear lens, up to the twenty-fifth year, is discission. Exceptionally, this age limit may be extended, but much beyond the twenty-fifth year the nucleus is apt to be too hard. The chief objection to discission is the slowness of absorption; it often takes months before the process is complete. Although this objection is a valid one, the patient need not lose all the time. Work may be resumed after the irritation has ceased in the eye operated on.

At the end of six to eight weeks a second discission, more free than the first and penetrating deeper into the lens, may be performed. It is to be assumed that by this time the process of absorption resulting from the first needling, has come to a standstill. In adults, it may require a year to eighteen months before the process of absorption, due to the discissions, is complete.

The density of the lens even up to the twenty-fifth year varies considerably so that in one case the capsular opening may result in a mere opaque line, while in another instance there may be marked opacity and swelling of the lens substance. As a rule, however, a large discission with deep penetration of the lens is apt to be followed by much reaction, especially swelling and opacity of the lens fibres, and in twenty-four to forty-eight hours, by increased tension, etc.

Most surgeons prefer to do a free discission followed by a linear extraction. If the reaction is slight ice cold compresses and the free use of atropine should be used, that the opacity and swelling of the lens may proceed moderately, without too many signs of irritation.

It is well to wait a sufficient time, so that the lens becomes fully opaque before proceeding to the next step, linear extraction. However, if the patient complains of much ocular pain, headache, pericorneal injection, contraction of the pupil, haziness of the cornea, and increased ocular tension, delay is dangerous and the swollen lens must be evacuated on the fourth or fifth day following the discission.

Dangers and complications of operations for high myopia. The untoward results liable to follow are: First, glaucoma; second, iritis, irido-cyclitis or panophthalmitis; third, infection.

The glaucoma occurs in two forms, inflammatory and non-inflammatory. Acute inflammatory glaucoma is the most frequent result of a too free discission, due to the irritation of the rapidly swelling lens substance, and comes on usually within the first five days following the operation. If severe, with neuralgic pains in the head and globe, nausea, vomiting, increased tension, and a hazy cornea, a linear extraction should be done without delay, permitting the evacuation of the swollen and opaque lens. This act dissipates all signs of inflammation, provided the operation is done at the onset of the symptoms.

There is a non-inflammatory or chronic form that occurs months or even years after operation, due to the contraction and thickening of capsular bands pulling on the ciliary process. Cutting these bands so as to prevent the traction, stops the process and this is done best with the scissors. The writer has seen a number of such cases where iridectomy proved of no avail and relief was only obtained by severing these capsular bands.

Iritis may occur, likewise irido-cyclitis may result from the too rapid swelling of the lens substance. These are best treated by leeches to the temple, the free use of atropine and hot compresses, temperature ranging from 120° to 130° F., continuously applied to the closed eyelids of the affected eye.

These conditions when severe are difficult to discriminate from infection, especially when the process results in panophthalmitis. It may be an open question as to what rôle infection played in leading to this result, the germ possibly being introduced at the time of operation.]

CHAPTER XVI.

REFRACTION AND ACCOMMODATION IN IRREGULAR ASTIGMATISM. CONICAL CORNEA. ILLUSTRATIVE CASES.

Before the days of the perfected ophthalmometer and other means of diagnosis no class of cases presented more difficulty in "fitting" than those with irregular curvature of the cornea.

In the Javal-Schiötz instrument the images of the mires are of service in detecting irregular astigmatism, just as with de Wecker's squares, that show distortion of the corneal image and irregularity of its outline when irregular astigmatism is present. It is also shown when there is no position on the cornea where the central lines dividing the mires can be made to form one continuous straight line. However, if regular astigmatism is present in addition to the irregular form, there are generally two positions at which these lines become more nearly straight than elsewhere, thus indicating the meridians of the regular astigmatism.

So delicate is the distortion test by means of the mires, that the slightest irregularity of the corneal surface is detected. This phenomenon should lead to a close inspection of the cornea by oblique illumination, and the probable detection of minute opacities, which otherwise might be overlooked.

The ophthalmometer, together with the disk of Placido (see p. 659, Vol. I and p. 6834, Vol. IX of this *Encyclopedia*) is also of the greatest value in finding the most regular part of a corneal surface affected with central or other scars or in certain cases of conical cornea. Mainly by the aid of these appliances what was at one time a most tedious and in many instances a hopeless task—the "fitting" of glasses in irregular astigmatism becomes a comparatively easy procedure.

Illustrative Cases.

Irregular astigmatism associated with a high degree of regular astigmatism following perforating ulcer of the cornea; Marked decrease both of the irregular and regular astigmatism, with attendant increase of vision in one year's time.

This is an interesting case, because of the changes in the shape of the cornea after the healing of an ulcer. These alterations were studied by means of the ophthalmometer, and noted for a long period. D. L., aged 32, first came under observation for treatment of ulcerative keratitis with hypopion. A large sloughing ulcer covered the lower half of the cornea, extending up almost to its centre; the anterior chamber was half full of pus. The patient recovered in two weeks but not without the ulcer perforating. Fortunately there was no iris prolapse, the pupil remained circular, central, and active, and the patient eventually perceived hand movements at 2 feet. A little over a month afterwards the eye was quiet, the pupil was central and active, and the lower outer quadrant of the cornea was covered by a dense opacity. The lower inner quadrant exhibited a diffuse opacity extending to the lower edge of the pupil.

Ophthalmometer: the right eye had .50 D. astigmatism with the rule, axis 120° + or 30° —; left eye showed marked irregular astigmatism, with a large amount of regular astigmatism with the rule, 12 D., axis 45° + or 135° —.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \text{not improved};$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{100} \text{ W.} - 9 \text{ D. cyl., } 135°.$$

Ophthalmoscope: H. 1 D. right eye. The fundus of the left eye is seen indistinctly, the outline of the disk is irregular, and the blood-vessels distorted and but partly seen; that is, a portion of a vessel was visible one moment, to be lost the next if either the ophthalmoscope or the patient's head moved.

Three months later a second test was made.

Ophthalmometer: The astigmatism was the same as at the first test in the right eye; in the left eye irregular astigmatism, not so marked as before, and regular astigmatism against the rule, 8.50 D., axis 15° + or 105° —.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} + \text{ : not improved;}$$

$$\text{L. V.} = \frac{20}{200} : \frac{20}{100} + \text{W.} - 7.50\text{ D. cyl., }105^\circ.$$

A little over a year after the first examination the following improvement was noted.

Ophthalmometer: Finding the same in the right eye as before; moderate amount of irregular astigmatism with regular astigmatism with the rule (as on the first test), 3 D., axis 45° + or 135° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} + \text{ : not improved;}$$

$$\text{L. V.} = \frac{20}{100} : \frac{20}{70}\text{ W.} - 3\text{ D. cyl., }135^\circ.$$

The most interesting feature of the case was the remarkable change in the character and amount of the astigmatism in the left eye. Twelve diopters of regular astigmatism with the rule associated with marked irregular astigmatism changed a little over three months' time to 8.50 D. *against the rule;* and then in nine months the regular astigmatism diminished to 3 D. *with the rule,* and returned to the same axis exactly as at first, and with marked improvement in the regular astigmatism.

Irregular astigmatism in each eye associated with a large amount of mixed regular astigmatism; Marked asthenopia; Vision considerably improved and asthenopia relieved by correcting lenses.

B, G., aged 21, general health only moderately good, has had trouble with her eyes since childhood, after an attack of measles. Three years ago had an attack of *la grippe,* which weakened her general strength very much; since then she has had recurrent ulcers on the margins of each cornea.

At present the corneæ have a row of dense opacities at the periphery about 3 mm. in diameter, separated by a small portion of clear cornea from each other. The opacities encircle the cornea and resemble the small scars left on the cornea after an episcleritis. The center of each cornea is clear, but the healing of the marginal ulcers has evidently caused some uneven tension of the cornea and, as a consequence (in the left eye especially) the surface of the clear portion of the cornea is uneven. This fact is made quite plain by the distortion of the images of the ophthalmometer mires and of the circles on Placido's disk.

The patient has been wearing glasses for two years, but they do not relieve the pain in her eyes and head.

Ophthalmometer: irregular astigmatism and regular astigmatism against the rule, 3 D., axis 135° + or 45° — right eye. Irregular astigmatism and regular astigmatism with the rule, 5 D., axis 75° + or 165° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{20} \text{ W.} + 2.75 \text{ D. cyl., } 135°;$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{50} \text{ W.} + 3.25 \text{ D. cyl., } 75° - .75 \text{ D. cyl., } 165°.$$

Reads Jaeger No. 1 from 5 to 15 inches.

Ophthalmoscope. H. 2 D. at 45 and M. 1 D. at 135 right eye; H. 3 D. at 165° and M. 1 D. at 75° left eye. The fundus of each eye is somewhat hazy and indistinct, and the measurement with the ophthalmoscope doubtful.

Second test one day later.

Ophthalmometer Irregular astigmatism in both eyes. Regular astigmatism against the rule, 2.75 D., axis 140° + or 50° — right eye; regular astigmatism with the rule, 4.50 D., axis 75° + or 165° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{20} \text{ — with } + 2 \text{ D. cyl., } 140° - .75 \text{ D. cyl., } 50°.$$

$$\text{L. V.} = \frac{20}{70} : \frac{20}{50} \text{ with } + 3 \text{ D. cyl., } 75° - .75 \text{ D. cyl., } 165°.$$

Two days later a third test was made with results like the second, and glasses were ordered as cross-cylinders. These glasses were worn constantly and proved satisfactory for the six months she was under obervation.

Slight irregular astigmatism associated with mixed astigmatism of large amount, against the rule, left eye; Emmetropia, right eye.

C. J. S., aged 27, in perfect health, came on account of poor vision in his left eye. Five years before he had had gonorrheal ophthalmia in this eye, with perforating ulcer of the cornea. There is a small dense opacity at the lower portion of the cornea, but with no anterior synechia; the pupil is central, circular, and active. He was fitted to glasses shortly after recovery from the ophthalmia, and these have given satisfaction until the last two months. The left eye has pained for the last two months after close work of any kind.

Ophthalmometer: regular astigmatism with the rule, .50 D., axis

90° + or 180° — right eye; slight irregular astigmatism, also regular astigmatism against the rule, 4 D., axis 140° + or 50° — left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{15}$: not improved.

L. V. = $\frac{20}{200}$: $\frac{20}{20}$ W. + 2 D. cyl., 140° — 1.50 D. cyl., 50°.

Reads Jaeger No. 1 from 6 to 21 inches.

Ophthalmoscope: H. .50 D. right eye; H. 2 D. at 50° and M. 2 D. at 140°, left eye.

Two days later, a second test was made, the patient accepting exactly the same glass as at the first test. Ordered a plane glass, right, and + 2 D. cyl., 140° — 1.50 D. cyl., 50°, left eye. The glasses gave him complete relief from pain in the eye.

This patient was kept under observation for more than two years, and at the end of that time he continued to wear the same glass with comfort.

The irregular astigmatism was but slight in this case, yet enough to be detected by the ophthalmometer, and this could be done especially when the arc was in the vertical meridian. The fact that the cornea was perfectly transparent at the point of intersection by the visual line allowed good vision when the regular astigmatism was corrected. The amount of amblyopia that is usually present in such cases was absent in this case, perhaps because the astigmatism was acquired, and not of the usual congenital origin.

Irregular astigmatism associated with a large amount of regular astigmatism with the rule in each eye; Antimetropia; Trichiasis; Asthenopia; Relief with operation and glasses.

W. B. L., aged 29, in good health, has been troubled with his eyes since he was fourteen years old. His ocular troubles began with inflammation of the lids, followed by "ulcers on the eyes," and for the last four years he has had "wild hairs" that he pulled out from time to time.

On account of the trichiasis and slight entropion of the left upper lid an operation was performed before glasses were fitted. Two weeks after the operation the first test was made.

Ophthalmometer: astigmatism with the rule, 6 D., 75° + or 165° —, with irregular astigmatism right eye; astigmatism with the rule, 6 D., 80° + or 170° —, with irregular astigmatism, left eye. In spite of the irregular astigmatism a marked regular astigmatism was present and measurable with reasonable accuracy.

Test cards and trial lenses.

R. V. = $\frac{10}{200}$: $\frac{20}{50}$ W. — 3.50 D. — 4.50 D. cyl., 170°.

$$\text{L. V.} = \frac{10}{200} : \frac{20}{50}\ \text{W.} + 4.50\ \text{D. cyl., } 80^\circ.$$

Reads Jaeger No. 1 at 8 inches.

Ophthalmoscope: M. 10 D. at 90° and 5 D. at 180° right eye; Em. at 90° and H. 5 D. at 180° left eye. There are a few fine, scattered opacities on the right cornea; on the left, especially at the upper margin, the punctate scars are more numerous, giving a faint, hazy view of the fundus.

Four days later a second test of the left eye was made, when the patient accepted the same glasses as at the first examination. The same cylinder was accepted by the right eye, but with a half diopter weaker spherical lens. Ordered: — 3 D. — 4.50 D. cyl., 170° right eye: + 4.50 D. cyl., 80° left eye.

This patient was kept under observation for fifteen months, and the glasses were at that time worn with satisfaction and relief from his asthenopic symptoms.

Considering the fact that this was a case of antimetropia, that a moderate degree of irregular astigmatism was present in each eye, together with a large amount of regular astigmatism, the result was gratifying. The axis of the cylinder in the right eye did not agree with the reading of the ophthalmometer by 5°, and 1.50 D. of astigmatism had to be deducted from the reading of the instrument in each eye, instead of .50 D. as is usually the case when the astigmatism is with the rule.

Irregular astigmatism associated with compound myopic astigmatism against the rule, left eye; Compound myopic astigmatism against the rule, right eye; Asthenopia; Relief with glasses.

S. M. B., aged 16, in good general health, came on account of poor vision and pain in the left eye. She had a perforating corneal ulcer when eight years of age, and since then has seen poorly in that eye. She does not see the blackboard well at school. The patient has worn — .50 D. sphere on each eye for the last six months, but with little improvement in vision.

Ophthalmometer: astigmatism with the rule, .50 D., axis 90° + or 180° —, right eye; irregular astigmatism, with regular astigmatism against the rule, 2.50 D., axis 30° + or 120° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{20} - \text{W.} - 1.25\ \text{D.}$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{70}\quad \text{W.} - 4\ \text{D.} - \text{cyl., } 120^\circ.$$

Reads Jaeger No. 1 from 4 to 15 inches.

Ophthalmoscope: M. 1 D. right eye; M. 4 D. at 120° and 6.50 D. at 30° left eye. There is an opacity on the left cornea about 3 mm.

in diameter, and an anterior synechia at the lower pupillary margin of the iris in the vertical meridian. The fundus in each eye is normal.

2nd test. *Ophthalmometer:* astigmatism with the rule, .25 D., axis 90° + or 180° —, right eye; the same reading in the left eye as at the first test.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{20}\ \text{W.} - .75\ \text{D.} - .25\ \text{D. cyl., } 90^\circ.$$

$$\text{L. V.} = \frac{10}{100} : \frac{20}{70}\ \text{W.} - 3.50\ \text{D.} - 2\ \text{D. cyl, } 120^\circ.$$

Reads Jaeger No. 1 from 4 to 15 inches.

The ophthalmoscope gave the same result as at the first test.

These last glasses were ordered to be worn constantly. They gave immediate relief and were worn for a little over a year with comfort, but at the end of that time she came again, complaining of pain in the eyes and of burning and itching of the eyelids. After treating the eyelids for a week the eyes were again tested with the following results:

Ophthalmometer: astigmatism with the rule, .25 D., axis 90° + or 180° —, right eye; irregular astigmatism and regular astigmatism with the rule, 2.50 D., axis 45° + or 135° — left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{20}\ \text{W.} - 1\ \text{D.} - .50\ \text{D. cyl., } 90^\circ.$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{70}\ \text{W.} - 3.50\ \text{D.} - 1.50\ \text{D. cyl., } 135^\circ.$$

Reads Jaeger No. 1 from 4 to 16 inches.

Ophthalmoscope: M. 1.50 D. right eye; M. 4 D. at 135° and M. 6 D. at 45° left eye. Normal fundus in each eye.

On a second test, the patient accepted the same glasses, and they were ordered. While under observation (two months) they have given relief from the pain in the eyes.

CHAPTER XVII.

REFRACTION AND ACCOMMODATION IN CONICAL CORNEA.

All the patience, skill and art the ophthalmic surgeon possesses must be exercised continually when testing for glasses in cases of conical cornea. In the lower grades the task is fairly easy but in advanced cases the task is a difficult one. The most valuable objective test is that with the ophthalmometer, and next to this instrument ranks the retinoscope. The subjective tests with trial lenses is often facilitated by the use of the stenopaic slit.

In conical cornea there is always more or less irregular astigmatism; and while the ophthalmometer is not capable either of measuring its amount or of placing its meridians with exactness, yet we are often able closely to approximate them. Even in extreme cases, when the center of the cornea is occupied by an opacity, or is so conical that it is no longer useful for visual purposes, the ophthalmometer and Placido's disk may enable us to select the most suitable and clearest portion of it outside of the center, near or in the visual area, that is best for visual purposes. If this favorable spot is too far from the visual area, and not directly in front of the pupil, an optical iridectomy (see p. 6578, Vol. IX of this *Encyclopedia*) may be performed behind it. Not only are we able to select this spot with the ophthalmometer but in many cases we may by its aid measure the local astigmatism (only approximately of course) and thus improve the vision—generally with cylinders. In the high degrees of astigmatism that obtain in conical cornea, and sometimes following cataract extraction, it is necessary to add an extra prism to the ophthalmometer, which, while it decreases the size of the image of the mires one-half, makes it possible to measure much higher degrees of astigmatism than with the usual prism.

See, also, **Keratoconus**, p. 6824, Vol. IX of this *Encyclopedia*.

The following case of conical cornea will serve to illustrate the points referred to.

Conical cornea, marked in the right eye, less in the left; Irregular astigmatism; No improvement with glasses in the right, but vision brought from 6/200 to 20/50 with glasses in the left eye.

N. F., aged 33, general health poor, being subject to sick headaches, especially severe at the menstrual periods. She had good sight until she was thirteen years of age, when she began to menstruate very profusely, losing great quantities of blood at each period, when the sight began to fail rapidly, particularly in the right eye. She became anemic, and her vision continued to grow worse for two years, after which time it appeared to remain about as it now is. She had considerable pain in the eyes for the first two years. Besides tonics, she has had prescribed minus 5 D., left, which gave her $\frac{20}{200}$, but no improvement in the right.

Ophthalmometer: astigmatism against the rule (about 4 D., axis

165° + or 75° +) with irregular astigmatism, right eye; astigmatism against the rule, 8 D., axis 30° + or 120° —, left eye, with irregular astigmatism.

Test cards and trial lenses.

R. V. $\frac{1}{200}$: not improved.

L. V. $\frac{6}{200}$: $\frac{20}{50}$ W. — 10 D. cyl., 120°.

Reads Jaeger No. 1 from 4 inches to 10 inches with the left eye.

Ophthalmoscope shows an extreme degree of conical cornea right, and a marked amount, left eye. The shadow-crescent of conical cornea is well shown in each eye, especially in the right, where it suggests an opacity of the lens, but oblique illumination shows a clear lens and transparent cornea. There were no opacities in the vitreous, and the fundus appeared normal.

Retinoscopy was useless in this case, and the ophthalmoscope was of but small service in the estimation of the refraction, as was the subjective test with the clock-dial. The ophthalmometer, the test case and trial lenses were the methods of value in deciding what lenses, if any, should be worn.

After several tests with and without a mydriatic, in which all of the results substantially agreed, we ordered for the right — 5 D. sphere (simply to balance the glass in the left eye), and for the left — 10 D. cyl., 120°, in the form of a periscopic sphero-cylinder. Instead of giving a — 10 D. cyl., 120°, a compound lens was ordered, — 5 D. — 10 D. cyl., 120° + 5 D. That is, a + 5 sphere was ground on one side of the glass, and — 5 D. sphere and — 10 D. cyl., 120° were ground on the other side. In effect, this glass is the same as the — 10 D. cyl., 120°. For reading, the patient was given the same lens in the right eye (— 5 D.) for distance; in the left, + 3.50 D. cyl., 30° — 6.50 D. cyl., 120°, which magnified the print more than the distance glasses.

The first few days the patient wore her glasses they made her very dizzy and she could not wear them in the street, but after a few days' trial she was able to go about at will; eventually ordered lenses both on the street and for reading. Her headaches were made worse and the attacks more frequent for the first few weeks after putting on the glasses; but her vision was so much improved that she persisted in the use of the glasses, and four months after the headaches were much less frequent and less severe. For the past few weeks she has not had a single headache.

We not only measured this patient's cornea near the center (where the visual lines cut), but 15° above, below, in, and out. We also located the extreme tip of the cone in each eye, which was down and out, between 7° and 8° from the center of the cornea in each.

The disk of Placido was of value in this case, and we give drawings of its reflections from the cornea in each eye. The marked flattening of the circles into regular ovals is well shown, the latter being more drawn out on the side away from the center of the cornea (see Figs. 107 and 108).

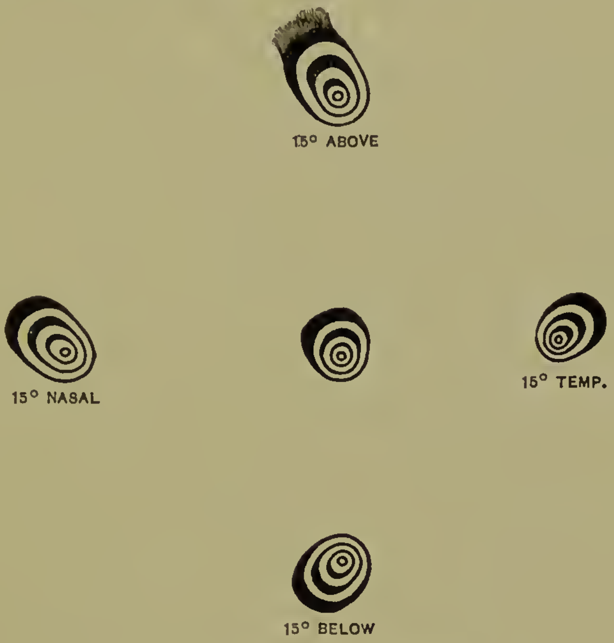


Fig. 107 (left eye). (After Davis.)

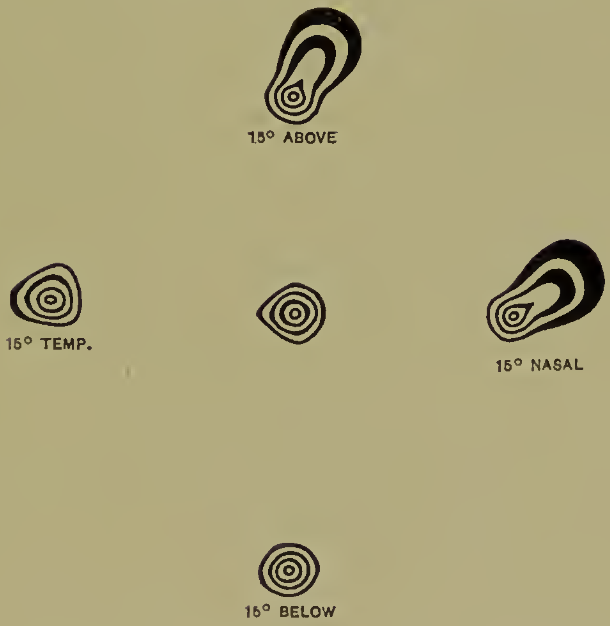


Fig. 108 (right eye). (After Davis.)

Right Eye: The Radius of Curvature at the Center (where the visual line intersects, in the meridian at 75° was 4.38 mm., with a refractive power of 76 D. The meridian at 165° had a radius of only 4.16 mm., with a refractive power of 80 D.

The ophthalmometric readings in this case, as indicating the radius of curvature and the refractive power of the cornea in its two chief meridians at various points on its surface are also given in the figure.

Of course these results are only approximate, because the aberration was marked and the irregular astigmatism so considerable that the images of the mires were indistinct and irregular in outline; not so indistinct, however, that approximate measurements could not be made. While the irregular astigmatism was very considerable, it was not nearly so evident as after many cases of cataract extraction, or in some instances of corneal opacity.

The radius of curvature of the cornea changed greatly in the same meridian; for instance, 15° below the center, in the meridian at 75°, the radius was 5.38 mm., that is, one mm. longer than at the center and with a refractive power of 62 D. as against 76 D. at the center. The radius in the meridian at 165° was 4.76 mm., with a refractive power of 70 D.

By these measurements it will be seen that while the radius of curvature has increased in length in each meridian, relatively it increased more rapidly in the meridian at 75° than it did at 165°. Therefore the astigmatism is much more marked 15° below the center of the cornea than at its center; in fact, just twice as great, or 8 D. The left eye could be measured with greater precision than the right because the cone was not so marked.

The radius of curvature at the center (in the meridian at 120°) was 6.20 mm., with a refractive power of 50 D., while the radius in the meridian at 30° was 5.96 mm., with a refractive power of 56 D. The mires of the ophthalmometer when turned from the second position, after being approximated back to the primary position, overlapped eight steps, indicating an astigmatism of 8 D. against the rule. In the right eye, there was a similar difference in the refractive power of the two chief meridians, estimated in the same way.

Fifteen degrees below the center (left) the ophthalmometer showed astigmatism against the rule, 5 D., 165° + or 75° —. The radius of curvature in the meridian at 75° was 6.18 mm., with a refractive power of 54 D., while the meridian at 165° had a radius of 5.75 mm., with a refractive power of 58 D. Fifteen degrees to the temporal side of the center of the cornea, the ophthalmometer showed astigmatism against the rule, 6 D., 150° + or 60° —. The radius of curvature in the meridians at 60° was 6.96 mm., with a refractive power of 48 D., while the meridian at 150° had a radius of 6.18 mm., with a refractive power of 54 D. Fifteen degrees above the center, the ophthalmometer showed astigmatism against the rule. 11 D., axis 15° + or 105° —. The radius of curvature in the meridian at 105° was 9.33 mm., with a refractive power of only 36 D., while the radius at 15° was 7.11 mm., with a refractive power of 47 D. Fifteen degrees to the nasal side of the center, the ophthalmometer showed astigmatism with the rule, 13 D., axis 75° + or 165° —. The radius at 75° was 7.11 mm., with a refractive power of 47 D., while the meridian at 165° had a radius of 9.88 mm., with a refractive power of 34 D.

Although both the chief meridians of the left eye at the center (the point cut by the visual line) had a radius of curvature much shorter than the average (7.82 mm.)—from which we would expect some myopia in addition to the astigmatism—nevertheless the patient would not accept a minus sphere; neither would she accept any plus glass, cylinder or sphere, either with or without a cycloplegic.

Irregular astigmatism complicating a compound hypermetropic astigmatism with the rule, right eye; Mixed astigmatism against the rule, left eye; Blepharitis and recurrent styes; Complete relief with glasses.

A. van E., aged 30, complains of redness of lids and that styes form now and then.

Ophthalmometer: astigmatism with the rule, 2 D., axis 90° + or 100°, right eye; astigmatism against the rule, 4.50 D., axis 10° + or 100°, left eye. Irregular astigmatism, each eye; corneal opacities.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{50} : \frac{20}{15} \text{ with } + .75 \text{ D.} = + 1.25 \text{ D. cyl., } 90^\circ.$$

$$\text{L. V.} = \frac{20}{200} : \frac{20}{40} \text{ with } - .50 \text{ D.} = + 4.50 \text{ D. cyl., } 10^\circ.$$

Reads Jaeger No. 1 from 5½ to 16 inches.

Ad. 8°, ab. 5°, sur. L. & R. 2°.

Ophthalmoscope shows: H. 1 D. at 90, and 2 D. at 180, right eye; H. 4 D. at 100, and M. 50 D. at 10, left eye.

The retinoscope confirms the subjective tests. Ordered:

R. + .75 D. = + 1.25 cyl., 90°.
L. — .50 D. = + 4.50 cyl., 10°.

This patient was seen again in four years, when the glasses were still satisfactory.

CHAPTER XVIII.

EXCEPTIONAL CASES OF REFRACTION.

By exceptional cases are meant those in which the results of the usual subjective examinations of ametropia differ widely from those indicated by the objective tests. An example of this condition occurs when the readings of the ophthalmometer differ from the subjective findings as much as 15°, as regards astigmatic meridians, and as much as 1 D. in the amount (except after cataract extraction) of the astigmatism. The following factors must be considered when dealing with exceptional cases of refractive errors and accommodative anomalies: abnormal lenticular astigmatism, from whatever cause; position of the lenses in front of the eyes; the angle alpha, and lack of centering of the cornea and the lens; astigmatism of the posterior surface of the cornea; contraction of the recti muscles; spherical aberration; imperfect instruments.

As before stated, the corneal astigmatism as measured by the ophthalmometer differs from the total astigmatism of the dioptric apparatus to the extent of about .50 D. to .75 D., in the great majority of cases. When the corneal astigmatism is "with the rule," the total astigmatism is found to be less than the corneal by .50 to .75 D.; when it is "against the rule" it exceeds the corneal by .50 to .75 D. Since the introduction of the ophthalmophakometer (see p. 8934, Vol. XII of this *Encyclopedia*) the lenticular astigmatism may be measured objectively.

Lenticular astigmatism. Javal, Nordenson, Schiötz, and others have established the undoubted fact that lenticular astigmatism amounts as a rule from .50 to .75 D. This may be called the normal astigmatism of the lens, just as we have about the same amount of astigmatism normally present in the cornea. As a rule the two, in practice, neutralize each other. Sometimes the lenticular astigmatism amounts to 1 or 1.50 D., or (rarely) even to 2 D., or more. In a case of *lenticonus anterior* in the writer's practice it was 7.50 D. See, also, p. 2877, Vol. IV and p. 7417, Vol. X of this *Encyclopedia.*

Javal (*Mémoires d'Ophtalmométrie,* p. 121) has reported a case of lenticular astigmatism of 2 D., Carl Weiland (*Archives of Ophthalm.,* Vol. XXII, 1893), one of similar amount, and George M. Black *(loc. cit.,* Vol. XXI, 1892) a lenticular astigmatism of 3.50 D. But all of these are exceptional cases. The lenticular astigmatism, as a rule, amounts to but .50 to .75 D., as proved by abundant statistics, and it has also been shown that, in actual practice the corneal astigmatism is diminished or increased that amount, accordingly as the astigmatism is with or against the rule. The most reasonable explanation to be given for the necessity of deducting .50 to .75 D. from the reading of the instrument when the astigmatism is with the rule and adding a like amount when the astigmatism is against the rule is the assumption that in corneal astigmatism with the rule there is usually associated a lenticular astigmatism of .50 to .75 D., in the same meridian, but of an opposite kind, thereby neutralizing that amount of corneal astigmatism. In astigmatism against the rule, there is, on the other hand a lenticular astigmatism of .50 to .75 D. in the same meridian and of the same kind, thereby adding that amount to the corneal astigmatism.

This can be explained in another way. In corneal astigmatism with the rule the lenticular astigmatism may be of the same kind but in a meridian at right angles to the corneal astigmatism; in which case, if the meridian at error in both the cornea and lens were myopic a simple myopia of .50 to .75 D. would be produced. In corneal astigmatism with the rule (by this explanation) the lenticular astigmatism must be of an opposite kind and in the meridian at right angles to the corneal, if the total is to amount to more than the corneal. However, the first explanation is more likely to be the true one, and, in fact, actual measurements (Donders) have shown it to be true; and the ophthalmophakometer confirms this view.

Regular lenticular astigmatism may be produced (1) by an oblique position of the lens, (2) by a slight displacement of the lens, as by sub-luxation, or (3) by unequal curvature of its surfaces. *Irregular lenticular astigmatism*, together with a large amount of regular lenticular astigmatism, may be caused by a marked luxation of the lens, when the edge of the lens lies in the pupillary space, by lenticular opacities (as in beginning cataract) and by lenticonus. We may also have a dynamic regular astigmatism produced by an unequal contraction of the ciliary muscle (Dobrowlsky, Javal). See p. 2871, Vol. IV; p. 6320, Vol. VII and p. 7202, Vol. X of this *Encyclopedia*.

Donders (*Refraction and Accommodation of the Eye*, pp. 532, 536) has reported two cases of lenticular astigmatism; one "from congenital eccentricity of the crystalline lens"; and the other due to an oblique position of the lens, with no, or only a slight, lateral displacement of the lens. The writer has observed such an anomaly in a case of aniridia. Here, because of the complete absence of the iris, the lens could be seen plainly. When the patient first came under observation the lens was vertical and not displaced, but in the course of eighteen months it became luxated upward to a slight extent (about 1½ mm.), and the upper edge of the lens was tilted backward. As a consequence, while the corneal astigmatism remained unchanged, the total astigmatism increased 1.50 D. This case is reported in full farther on in this section.

Again, astigmatism of the lens may be caused by an unequal curvature of its surface, just as in the cornea. Moreover, the principal meridians of the lens may not coincide with the principal meridians of the cornea.

In young subjects we may have a regular astigmatism (dynamic) of the lens, produced by an unequal contraction of the ciliary muscle.

Such an astigmatism is shown by paralyzing the accommodation with atropin, when the eye with a corneal astigmatism (shown by the ophthalmometer) that accepted no correction before the use of a cycloplegic, takes a cylindrical glass after its employment. From this evidence it is conclusive that corneal astigmatism must have been corrected, in whole or part, by a lenticular astigmatism, most probably due to an uneven or irregular contraction of the ciliary muscle.

Luxation of the lens not only produces irregular astigmatism, but causes monocular diplopia, by a part of the lens in the pupil acting as a prism. Moreover, the refraction of the rays of light is so different in the two halves of the pupil that everything is confused to the patient. In such cases, it is best, as a rule, to fit the aphakial part of the pupil, ignoring altogether the half with the lens, as the best vision is to be obtained by so doing. Such strong glasses blur the images completely for the part of the pupil with the lens in it, and this does away with the double vision or at least for the eyes singly, although it may be present when both eyes are used together.

Lenticular opacities, as in beginning cataract, produce irregular astigmatism and often cause diplopia. This is due to the different sectors of the lens becoming unequally swollen or distorted and refracting light rays independently, so that monocular diplopia or polyopia results. Glasses do not improve vision much or at all in such cases.

There are a certain number of cases of refractive monocular diplopia and polyopia that are not due to lenticular opacities, and which are entirely relieved by glasses. St. John Roosa (*Defective Eyesight*) emphasized this point, and says "the double vision quite often seen in hypermetropia, or hypermetropic astigmatism, a diplopia which is not constant, may always be relieved by a correction of the error of refraction. G. J. Bull has shown that this so-called vision is often to be described as the imperfect superposition of a series of faint multiples of the original letter. I believe that this is the correct view of quite a number of cases of polyopia monocularis. It explains the ease with which such cases are treated by correction of the error of refraction. The observer who will make himself astigmatic to a considerable degree will, in an instant, recognize this doubling of vision, which is the result of an uncorrected error of refraction in the eye, and has nothing to do with insufficiency of the muscles."

Lenticonus may be a cause of irregular astigmatism, together with a large amount of regular astigmatism, though such cases are exceedingly rare.

The position of the glass in front of the eye has already been considered in speaking of the correction of high degrees of hypermetropia.

Angle alpha. This angle, as it is well known, is formed by the visual axis and the optic axis, the former usually a tangent of the cornea four or five degrees to the nasal side of the center of the cornea, while the optic axis passes through the cornea at its center. See p. 470, Vol. I of this *Encyclopedia*.

Ordinarily, when using the ophthalmometer, we do not measure the center or summit of the cornea, but an area about 5° to the nasal side of its center, for we direct the patient to look into the center of the tube. To be *exact* in measuring the astigmatism of the cornea we should find the angle alpha first, then have the patient look a corresponding number of degrees to the nasal side so that the center of the cornea is brought into position to be measured. That the astigmatism of these two areas may be different has been shown by Helmholtz, Donders, Knapp, and others. Knapp showed that the refractive power of the cornea in one and the same meridian at a distance of 1.25 mm. from the center of the cornea (about 7°) varied as much as one-third diopter; and since the angle alpha may amount in exceptional instances to as much as 12°, it is easy to see how the astigmatism at that distance from the center of the cornea might differ from that at the center. In fact, where the astigmatism is of high amount and the angle alpha large, it can be shown clinically that the astigmatism varies in the two localities. Donders has shown that the surface of the cornea 15° from the center becomes rapidly flatter from that distance on to its periphery. It must be remembered that in using the ophthalmometer we do not measure the whole of the cornea, but only a small portion of it—about 12° to 15° (2.50 to 3 mm.) in diameter—with its center at the point cut by the visual line. It can be readily understood that, if this point is 12° to the nasal side of the center of the cornea, the point from which the image of one of the mires is reflected, when measuring the horizontal meridian, must be still farther from the center of the cornea. At such a distance from the center of the cornea the surface is considerably flatter than at the center, and the error in measurement in such an instance would likely be considerable, especially if the astigmatism happened to be of high amount. Of course, it is altogether exceptional to have an angle alpha of 12°, because, it rarely amounts to more than 5°, and often not to more than 2° or 3°. It may, therefore, except in very high degrees of astigmatism, be left out of consideration altogether.

By means of the disk (of Placido) on the ophthalmometer the center of the cornea is easily ascertained by having the patient look at the circle marked with the number of degrees corresponding to the angle alpha—to the nasal side when the angle is positive (as it usually is) and to the temporal side when it is negative. And this stands as an additional reason why the Placido disk should not be removed from the ophthalmometer, and replaced by a plain black disc, as is done by some instrument makers.

Astigmatism of the posterior surface of the cornea. The posterior surface of the cornea may be astigmatic, just as the anterior surface, rendered so by its principal meridians having unequal length of radii of curvature. Tscherning has invented an instrument, the ophthalmophakometer, for measuring the posterior surface of the cornea, also for measuring the surfaces of the lens. This instrument is described by A. Javal (*System of Diseases of the Eye,* Vol. II, p. 135) and by Tscherning himself (*Physiological Optics,* trans. by Weiland, p. 64). See the first part of this section for a description of the instrument and its mode of employment.

By actual measurements the posterior surface of the cornea is shown to have a slightly shorter radius of curvature than the anterior surface. Javal (*loco cit.,* p. 137) commenting on this observation, says: "The posterior surface of the cornea is found to diminish in curvature from the center towards the periphery, as in the case of the anterior surface, and in case of corneal asymmetry it appears also, as might be expected, to follow the asymmetry of the anterior surface. As a concave lens of asymmetrical curvature, the effect of the cornea is to compensate in some degree the astigmatism of the anterior corneal surface as measured by the ophthalmometer. The maximum compensation due to this cause, so far as has been observed, is about 1 D. (as estimated for an eye in which the total astigmatism measured about 6 D.)."

Contraction of the recti muscles. In a few cases the recti muscles can, by voluntary action, alter the corneal astigmatism. The writer reported such a case in the *Manhattan Eye and Ear Hospital Reports* for January, 1895. The patient had a corneal astigmatism with the rule of .50 D. which he could, by voluntary action of the recti muscles, increase to 2 D. in the right eye, and to 1.50 D. in the left eye. Under a cycloplegic he could still increase the astigmatism in the right eye to 1.50 D., and in the left eye to 1 D. The lids were held from the eye so that they could not influence the result.

This form of error might be called a *dynamic corneal astigmatism,* just as we may have a dynamic lenticular astigmatism caused by an unequal contraction of the ciliary muscle.

Spherical aberration. In very high degrees of astigmatism the images of the mires are affected by spherical aberration, and on this account record an excess of error. Leroy and Reid have dwelt upon this point and insist that the proper reduction in the astigmatism measured by the ophthalmometer has to be made if it is to accord with that found on subjective examination. See p. 23, Vol. I of this *Encyclopedia.*

CHAPTER XIX.

CASES EXHIBITING DIFFERENCES BETWEEN OPHTHALMOMETRIC MEASUREMENTS AND SUBJECTIVE FINDINGS.

Corneal astigmatism, 2.50, with the rule; Total astigmatism 1.25 D. by subjective examination.

H. H., aged 30, in good health, has worn glasses for three or four years; came on account of headaches and pains in the eyes, especially after using the eyes for close work.

Ophthalmometer. Astigmatism with the rule, 2.50 D., axis 90° + or 180° — in each eye.

Test cards and trial lenses.

R. V. = $\frac{20}{50}$: $\frac{20}{20}$ + W. — 1.25 D. cyl., 180°.

L. V. = $\frac{20}{50}$: $\frac{20}{20}$ + W. — 1.25 D. cyl., 180°.

Reads Jaeger No. 1 from 7 to 15 inches.

Ophthalmoscope. Em. at 180° and M. at 1.50 D. at 90° in each eye. After a second and third test the patient would not accept a stronger cylinder with improvement in vision.

In this case 1.25 D. had to be deducted from the corneal astigmatism as measured by the ophthalmometer, or, what amounted to the same thing, the patient would not accept the cylinder to correct the astigmatism, as indicated by the instrument, by 1.25 D. She was under observation for more than two years, and when last seen the glasses were satisfactory and the eyes comfortable.

Corneal astigmatism with the rule, 1 D. right and 1.50 D. left eye. Patient will accept no cylindrical glass; Antimetropia; Presbyopia.

K. E. H., aged 43, in robust health, has never worn glasses, though she has seen poorly with the right eye since childhood.

Ophthalmometer. Astigmatism with the rule, 1 D. 90° + or 180° —, right eye; 1.50 D. 90° + or 180° —, left eye.

Test cards and trial lenses.

R. V. = $\frac{6}{200}$: $\frac{20}{100}$ W. — 13 D.

$$\text{L. V.} = \frac{20}{20} : \text{will accept no glass.}$$

Reads Jaeger No. 1 from 8 to 20 inches, with + 1.25 D. sphere left eye; has not single binocular vision, the patient using the left eye for both the distance and the near point.

Ophthalmoscope. M. 13 D., with posterior staphyloma and choroidal changes, right; Em. left eye.

In this case there was a corneal astigmatism in the better eye of 1.50 D., which was probably neutralized by a like amount of lenticular astgimatism. Be that as it may, the simple spherical glasses are perfectly satisfactory, a + 1.25 D. being ordered for each eye. Of course no attempt was made to "fit" the right.

Congenital absence of the iris; Corneal astigmatism with the rule, 1.50 D. right and 2 D. left, axis 5° and 175°, respectively; Total astigmatism 1 D. each eye, with the same axis as the corneal astigmatism; In eighteen months' time the corneal astigmatism did not change, but the total increased to 2.50 D. in each eye, axis 180° each, due to slight luxation upward and tilting backward of the upper edges of the crystalline lenses. Coloboma of the right lens.

A. M. B., aged 6, was brought by her mother. Soon after the birth of her child she noticed something peculiar about the eyes. As the patient grew up she avoided bright lights and shut the eyes when in the sunlight. The child has always enjoyed good health except for the ocular trouble and defect. Since the birth of this, the first child, the mother has been delivered of two other children, sound in every respect. Both the father and mother are healthy and without defect, and the mother says that this is the first member of either her or her husband's family thus afflicted. The father, mother, and two younger children are all slightly hypermetropic, while the patient has compound myopic astigmatism.

The *ophthalmometer* reveals astigmatism with the rule, 1.50 D., axis 95° + or 5° —, right eye; 2 D. 85° + or 175°, left eye. The ophthalmoscope shows complete absence of the iris in each eye, with nothing but a very narrow pigment-ring at the extreme periphery of the cornea. None of the ciliary processes can be seen either with the ophthalmoscope or by oblique illumination. The lenses are transparent and circular, except a slight nick in the lower edge of the right. The vitreous is clear and the fundus normal in each eye. The fibres of the zonule of Zinn can be seen distinctly below and at the sides, but not so plainly above, as the lenses are slightly displaced upward. The diameter of the lenses can be seen with the ophthalmoscope to become distinctly smaller when the patient makes strong efforts at accommodation.

$$\text{R. V.} = \frac{20}{100} : \frac{20}{50} \text{ with } - 4.50 \text{ D.} - 1 \text{ D. cyl., } 5^\circ.$$

$$\text{L. V.} = \frac{20}{200} : \frac{20}{70} \text{ with} - 5\text{ D.} - 1\text{ D. cyl., } 175^\circ.$$

Reads Jaeger No. 2 at 8 inches with these glasses.

The above lenses (No. 2 London-smoke, to keep the excessive light from the eyes) were ordered. With these the patient pursued her studies with comfort for eighteen months. The tension of the eye has remained normal.

This case was reported to the New York Ophthalmological Society eighteen months after her first visit. The vision at that date was about the same as when the patient first came under observation. The corneal astigmatism was exactly the same, but the total amount had increased considerably (1.50 D. in each eye) owing to the displacement of the lenses a little upward, the upper margins being tilted slightly backward. The myopia has also increased to some extent. The patient then accepted — 5 D. — 2.50 D. cyl., 180° right, and — 6 D. — 2.50 D. cyl., 180° left. The lenses remained clear except faint striæ in their lower halves. The luxation upward is not more than 1 to 1½ mm., and not enough to cause diplopia.

After six years the patient accepted — 6 D. $\bigcirc$ — 3 cyl. ax. 180°, each eye.

Distinct striæ were discovered in the lower part of each lens. Thirteen years afterward the patient was seen again, when the lenses had become almost completely opaque, and still farther displaced upward. Vision was reduced to 15/200 each eye.

In this case there is no question but that the increase in the total astigmatism was due to the upward luxation and backward tilting of the upper edge of the crystalline lens. This displacement and tilting could be seen plainly because of the absence of the iris. The ophthalmometer showed absolutely no increase in the corneal astigmatism.

Antimetropia; Severe headaches; Complete relief with glasses.

J. W. G., aged 37, complains of headaches and pains in the eyes: is sick at the stomach at times. She wears

+ .50 D. = + .50 D. cyl., 90°, right;
— 4.50 D. = — 2.50 D. cyl. 180°, left.

Ophthalmometer: astigmatism with the rule, 1.25 D., axis 85 + 175 minus, right eye; astigmatism with the rule, 3 D., axis 90 + 180 minus, left eye.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15} \text{ with} + .50\text{ D.} \bigcirc + .75\text{ D. cyl. } 80^\circ.$$

$$\text{L. V.} = \frac{5}{200} : \frac{20}{70} + \text{ with} - 7.50\text{ D.} \bigcirc - 2.75\text{ D. cyl. } 180^\circ.$$

Reads Jaeger No. 1 at 7 to 18 inches.

Ophthalmoscope: H. 1 D. at 90° and 1.50 D. at 170° right eye;

myopia, 9 D. at 90° and 6 D. at 180° left eye. Posterior staphyloma in the left eye. Ad. 14°, ab. 6°, sur. R. and L. 5°.

Under homatropin:

$$\text{R. V.} = \frac{20}{50} : \frac{20}{15} \text{ with } + 1 \text{ D.} \bigcirc + .75 \text{ cyl., } 80^\circ.$$

$$\text{L. V.} = \frac{5}{100} : \frac{20}{50} \text{ with } - 6.50 \text{ D.} \bigcirc - 2.75 \text{ cyl., } 180^\circ.$$

Ordered: + .75 D. ○ + 75 cyl., 80°; — 5.50 D. ○ — 2.75 cyl., 180°. Eyes entirely comfortable; no more sickness at the stomach. Has single binocular vision. Ad. 14°, ab. 6°, sur. R. & L. 5°. With glasses off has tendency to converge 3° to 5°; interpupillary distance 58 mm.

Polyopia due to astigmatism: E. M. B., aged 25. There is double (sometimes quadruple) vision in the left eye, especially when she looks at lights. The distortion began in 1908 in the left eye, when a light assumed the shape of the letter Y, having two forks above and one below. A similar phenomenon was observed in the right eye in 1910. Her cat sometime ago appeared to have four tails.

Ophthalmometer: astigmatism with the rule, 1.50 D., axis 75 + 165 —, right eye; astigmatism with the rule, 3.25 D., axis 90 + 180 —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{20} : \frac{20}{15} + \text{ with } + 1.25 \text{ cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{20} : \frac{20}{20} \text{ with } + 150 \text{ cyl. } 95^\circ - .75^\circ \text{ cyl., } 5^\circ.$$

Reads Jaeger No. 1 from 6 to 18 inches. Ad. 8°, ab. 5°, sur. R. & L. 2°.

Ophthalmoscope: emmetropia in the vertical meridian and 1 D. of H. in the horizontal, right eye; 1 D. of M.; vertical, and 1 D. of H. in the horizontal, left eye. Normal fundi. Patient suffers from indigestion. She has had another attack of double vision since last visit, either using both eyes at once or in the left eye alone.

Under homatropin:

$$\text{R. V.} = \frac{20}{15} + \text{W.} + 1.25 \text{ cyl., } 75^\circ.$$

$$\text{L. V.} = \frac{20}{15} \text{ W.} + 1.50 \text{ cyl., } 100^\circ - 75 \text{ cyl., } 10^\circ.$$

The retinoscopic and ophthalmoscopic findings confirmed the subjective tests. Ordered: + 1.25 cyl., 75°, right; + 2.25 cyl., 100° = — 75 D., left.

Lenticonus anterior; Corneal astigmatism with the rule, 2 D. in each eye; Total astigmatism against the rule (5.50 D.) in right, and 4 D. in the left eye; Vision greatly improved with glasses.

J. L. H., aged 57, in good health, a lawyer, came because of migraine affecting the right side of his head, and pain in the right eye. Four days previously he had an attack that was so severe that he was confined to bed all day, and has been incapacitated for work ever since. The pain extends from the right side of the head to the right eye. He has had such attacks before, but they were not so marked. There is no redness of the eye, no plus tension, or other indication of glaucoma. He has worn reading glasses for fifteen years, with which he gets fairly good vision. He has never seen very well either for distance or for near. He now wears for reading + 2.50 D. cyl. ○ 180° — 3 D. cyl., 90°, right eye; + 2.50 D. cyl., 180° ○ — 1.50 cyl., 90° left eye.

Ophthalmometer: astigmatism with the rule, 2 D. ax. 90 + 180 —, right eye; 2 D., axis 75° + or 165° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{200} : \frac{20}{100} \text{ with } - 2.50 \text{ D.} - 2.50 \text{ D. cyl., } 90°.$$

$$\text{L. V.} = \frac{20}{200} : \frac{20}{50} \text{ with } - 1.50 \text{ D.} - 2.50 \text{ D. cyl., } 75°.$$

Reads Jaeger No. 1 from 7 to 12 inches, with + 1 D., — 2.50 D. cyl., 90° right, and + 2 D. — 2.50 D. cyl., 75° left.

Because of the great difference between the astigmatism indicated by the ophthalmometer and that found on subjective examination, the writer suspected some trouble with the lens, an incipient cataract perhaps. However, on examination no opacity was found, but there was a transparent protuberance of a conical shape on the anterior surface of the crystalline in each eye. (See Fig. 104.) The corneæ were perfectly clear, except for a minute opacity just to the outer side of the center of the left. The shadows reflected from the pupil resembled in marked degree the shadow crescents seen in conical cornea. No double image of the fundus by the direct method could be obtained with the ophtahlmoscope as did Webster (*Archives of Ophthalm., and Otol.*, Vol. IV, p. 382, 1874-5) in his case, the first of the kind reported; however, the pupil was not dilated as in his case, and besides, the conicity was not so marked in this case as in his, so far as can be judged by reading the published account and looking at the excellent diagrams he gave. With the indirect method, however, a decided doubling of the retinal blood-vessels, both vertical and horizontal, was obtained. This phenomenon was also observed with the parallactic movement, when the double images could be made to approach or to recede from each other by the slightest movement of the ophthalmoscope or object lens. The fundus was normal in each eye.

On a second test the ophthalmometer gave exactly the same reading as at first.

Test cards and trial lenses.

R. V. = $\frac{20}{200} : \frac{20}{50}$ W. — 5 D. — 2.50 D. cyl., 90°.

L. V. = $\frac{20}{200} : \frac{20}{30}$ — W. — 1 D. — 3 D. cyl., 75°.

Reads Jaeger No. 1, 9 to 15 inches, with — 1 D. — 2.50 D. cyl., 90° right; + 3 D. cyl., 165° left eye. These reading glasses were prescribed, and have been worn for more than three years with comfort.

This patient, according to the glasses he wore when he first came, had a total astigmatism in the right eye of 5.50 D., and in the left eye 4 D. in each against the rule. Hence, the crystalline must have had an astigmatism of 7.50 D. in the right, and 6 D. in the left, against the rule in each, in order to have the total astigmatism amount to 5.50 D. right and 4 D. left, against the rule. According to the tests made by the writer he must have had a lenticular astigmatism against the rule of 4.50 D., right, and 5 D., left, in order to have a total astigmatism against the rule of 2.5 D., right, and 3 D., left, because he had 2 D. of corneal astigmatism with the rule in each eye.

Corneal astigmatism with the rule; The principal meridians not at right angles.

N. S., aged 25, in good health, has worn glasses off and on for the last ten years, but none have given her relief from a very troublesome asthenopia. She was fitted twice with glasses while under the influence of a cycloplegic.

Ophthalmometer. Astigmatism with the rule, 1 D., the images "lining" at 165° in the first position, and at 60° in second position, right eye; .75 D., the images at 15° in the first position, and at 120° in second position, left eye.

Test cards and trial lenses.

R. V. = $\frac{20}{30} : \frac{20}{20}$ W. + 1.75 D. + .50 D. cyl., 60°.

L. V. = $\frac{20}{30} : \frac{20}{20}$ W. + 1.25 D. + .50 D. cyl., 120°.

Reads Jaeger No. 1 from 6 to 20 inches.

Ophthalmoscope. H. 2.50 D., right eye; H. 2 D., left eye; normal fundi; no opacities in the corneæ or lenses.

A second and third test gave the same result, and the ophthalmometer the same reading in all three tests. The corresponding glasses were ordered, and gave immediate relief from the asthenopia.

The patient was seen two years afterward. She had meantime used her eyes constantly as an artist, and the glasses were still entirely satisfactory.

Corneal astigmatism with the principal meridians not at right angles in the right eye.

J. E. M., aged 58, in good health, came because her eyes (especially the right one) had a "sore feeling" in them and became red after using them for close work. She has worn glasses for a number of years; the last pair (+ 2.25 D. spheres) for eight years.

Ophthalmometer. Astigmatism with the rule, 1 D., the images "lining" at 180° in the first position, at 75° in the second position, right eye; 50 D., axis 90° + or 180° — left eye.

Test cards and trial lenses.

R. V. $= \frac{20}{20} -$: $\frac{20}{20}$ W. — .50 D. cyl., 180°.

L. V. $= \frac{20}{20} -$: not improved with any glass.

Reads Jaeger No. 1 from 8 to 16 inches, with plus 3 D. sphere added.

Ophthalmoscope. Em. in each eye. There is no opacity of the lenses or the corneæ, and the fundi are normal.

The reading glasses were ordered, + 2.50 D. + .50 D. cyl., 90°, right; and + 3 D. sphere, left. These lenses relieved the asthenopia. Both in this case and in the one immediately preceding it, the cylinders accepted were not at right angles to the meridian at error. In the right eye, previous case, the accepted cylinder had its axis at 60°, while the least curved meridian was at 165° (as shown by the images "lining" at that point) while, to be worn at right angles, its axis should have been at 75°. In the left eye the plus cylinder was accepted at 120°, but the least curved meridian was at 15°. So in the present case, in the right eye the most curved meridian was found to lie at 75°, nevertheless, the patient accepted a minus cylinder, axis 180°, while it should have been worn at 165°, to be at right angles to 75°.

Where the principal meridians are not at right angles, the patient may accept the cylinders with their axes exactly at right angles to the meridians at error; hence it is well in such cases to try the cylinders at both the positions indicated by the ophthalmometer, for example at 15°, or at any number of degrees of inclination the chief meridians have toward each other. The retinoscope and ophthalmophakometer are of great value in these cases.

Large amount of astigmatism; The corneal and total astigmatism corresponding closely as to amount and axis; Patient accepts the glasses indicated by the ophthalmometer with marked improvement in vision, but cannot wear any cylindrical correction, preferring simple spheres.

K. N., aged 37, in good health, came for change of glasses. She has worn spherical glasses for close work, but not for distance, for ten years. None have ever been entirely comfortable to the eyes. She complains now of occasional headache and pains in the eyes, especially in the afternoon and evening.

Ophthalmometer. Astigmatism with the rule, 1.25 D., axis 120° + or 30° —, right eye; 5.50 D., axis 80° + or 170° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{20}{30} : \frac{20}{20} \text{ with } + .75 \text{ D. cyl., } 120^\circ.$$

$$\text{L. V.} = \frac{10}{200} : \frac{20}{50} \text{ with } + 4.50 \text{ D. cyl., } 80^\circ.$$

Reads Jaeger No. 1 from 8 to 15 inches.

Ophthalmoscope. Em. at 120° and H. 1 D. at 30° right eye; Em. at 75° and H. 5 D. at 165° left. No opacities of the cornea or lens in either eye. No muscle insufficiency. A second test was given, and as the patient accepted the same glasses as at first they were ordered.

The patient tried faithfully to wear them for two months, but claimed they did not help her in the least, in fact, that they made the vision worse, because they elongated objects very much in the horizontal meridian. A simple + 2 D. sphere in each eye gave her more comfort than any other lens, and these she continued to wear till her death four years later.

In this case, as well as the one to follow, little or no difference in the axis or the amount of the astigmatism was discovered by the various objective and subjective tests. Nevertheless the patients were not able to wear any cylindrical correction whatever. In seeking an explanation of the behavior of the eyes in these two cases, and in others like them, especially in presbyopes who have never worn any correction in early life, or only a spherical one, light is thrown upon the mystery by Donders (*loco cit.*, p. 509). He observes that "The correction of regular astigmatism by means of cylindrical glasses is incapable of absolute perfection. Apart from the amblyopia, which, independently of the light-refracting system, complicates many cases of astigmatism, the acuteness of vision must, even with the most accurate correction, leave something to be desired, because the asymmetry of the astigmatic eye cannot be completely counteracted by the presence of a cylindrical lens. Moreover, the correction is only of that nature that the posterior focal points for the different meridians are brought together without the same being true of the other cardinal points. The absolute coincidence of the nodal points in the different meridians is scarcely attainable. If they lie in the principal meridian of slightest curvature more posteriorly, correction with a biconvex cylindrical lens brings them more forward than those in the meridian of greatest curvature; and vice versa if they be situated more anteriorly, on correction by a biconcave cylindrical lens, they are moved more backward. In this is implied that the form of the bodies, on correction of astigmatism, is elongated in a direction opposite to that in which, before correction, elongation existed.'' In other words, high-degree astigmatics whose distant vision has been uncorrected till late in life have become accustomed to images of objects much elongated in a certain direction, and when we try to correct their astigmatism we greatly elongate the images in another direction. This is so disturbing to all previous conceptions of the form and size of objects that some patients cannot bear it, even though their eyesight, so far as test-types are concerned, is greatly improved by the lenses suggested. In both of the cases here reported the meridians of the astigmatism were oblique, and this of itself made it much more difficult for them to become accustomed to cylinders.

Corneal astigmatism against the rule, with oblique axes; Total astigmatism exactly the same in each as to axis and almost identical as to amount; Patient's vision greatly improved by cylindrical correction, yet he cannot wear it.

G. H. W., aged 68, in very good health considering his years, came for reading glasses. He has never worn glasses for distance, but spherical lenses for near vision since he was forty-five years old. With these he has gotten along fairly well, though his vision has always been rather poor.

Ophthalmometer. Astigmatism against the rule, 2.50 D., axis 5° + or 95° —, right eye; against the rule, .50 D., axis 170° + or 80° —, left eye.

Test cards and trial lenses.

$$\text{R. V.} = \frac{15}{200} : \frac{20}{50}\ \text{W.} + 2.50\ \text{D. cyl.}, 5^\circ.$$

$$\text{L. V.} = \frac{20}{100} : \frac{20}{20}\ \text{W.} + 1.50\ \text{D.} + .75\ \text{D. cyl.}, 170^\circ.$$

Reads Jaeger No. 1 from 9 to 20 inches, with + 4 D. sphere added.

Ophthalmoscope. H. 2.50 D. ax. 95°, and Em. at 5°, right; H. 2 D. at 90° and H. 1 D. at 180°, left; normal fundi; no opacities of the refractive media.

The indicated reading glasses were prescribed, and the patient made persistent efforts to use them for six weeks, but finally gave them up because of the elongation of letters and other printed matter in the vertical meridian. With simple spherical glasses he got tolerably clear vision for reading (the print appearing of natural shape) even if objects did not seem as distinct as with the cylindrical correction.—(A. E. D.)

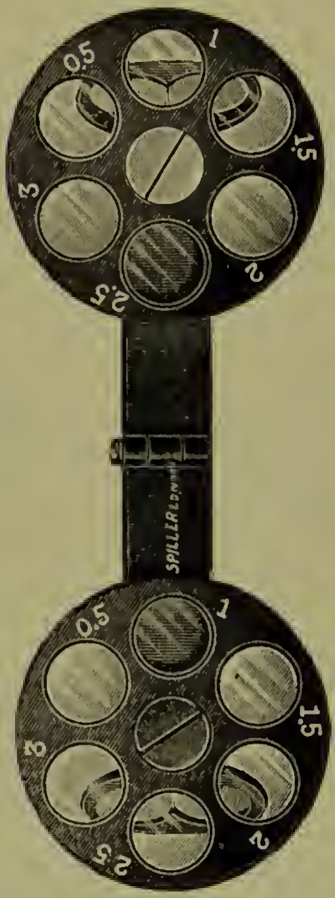
Refraction circle. An instrument by means of which indices of refraction can be measured.

Refractionist. One skilled in measuring the refraction of the eye.

Refraction, Vertex. See **Lenses and prisms, Ophthalmic,** p. 7257, Vol. X of this *Encyclopedia.*

Refractometer. An instrument for measuring the refractive power of the eye.

Grossman's refractometer and astigmometer consists of a series of spherical and cylindrical lenses, the latter rotating by means of a toothed rod. The apparatus, which is not intended to leave the hand of the examiner, takes the place of the trial case and frame during the preliminary examination.



The "Bishop-Harman" Pocket Refractometer.

Refrangible. Capable of being refracted.

Refringent. Of, or pertaining to, refraction; refracting.

Regard, plane of. A plane that passes through the center of rotation and the point of fixation in the eye.

Regenbogenhaut. (G.) Iris.

Regeneration of the cornea. See p. 3437, Vol. V of this *Encyclopedia.*

Regio, Barnabas de. The well-nigh unknown author of a work on ocular hygiene, entitled *"Libellus de Conservanda Sanitate Oculorum,"* composed in 1340 and possessed of little value. See **Barnabas de Regio**.—(T. H. S.)

Region, Ciliary. The part of the eye occupied by the ciliary body and its adjuncts.

Region, Opticostriate. The basal ganglia and the capsule.

Region of accommodation. According to Donders, this is only the expression of the distance between *r* and *p*, and is therefore equal to R—P; while the range of accommodation is a dioptric value, proportional to the focal distance of the lens, which expresses the difference of accommodation for P and R. The region of *a.* is quite altered by lenses, and there is no proportion whatever between it and the range of *a.*

Registering keratoscope. Astigmometer.

Regressive cataract. A cataract that undergoes regressive change and tends to disappear; usually occurring in young persons as a symptom of interference with the nutrition of the lens, but occasionally observed in cases of ordinary senile cataract.

Regular reflection. Reflection in which the incident and reflected rays make equal angles with the normal to the surface at the point of incidence.

Rehabilitation of the blind. See **Re-education of the blinded.**

Reichenbach, Johann Freidrich. An 18th century ophthalmologist of Tübingen, Germany, whose life dates cannot be ascertained. He was a pupil of Mauchart, studied at Strassburg and at Paris, and seems to have been a skilful operator. His dissertation for the doctorate was entitled *Cautelæ et Observationes circa Extractionem Cataractae, Novam Methodum Synezesin Operandi Sistentes, etc., 2 Dec. 1767.*—(T. H. S.)

Reid, Thomas. A well-known Glasgow ophthalmologist, inventor of the widely used Reid's portable ophthalmometer. Born at Calsburgh, in the parish of Shotts, Scotland, in 1830, he became renowned for his great scholarship very early in life. In fact, at the age of twelve he read all the books in the village library, and knew some of them by heart. For a time he was apprentice to a cabinet-maker at Airdrie, but later began to study medicine at Anderson College. Migrating later to the University of Glasgow, he there received his medical degree in 1857. Immediately after graduation, and because of ill health, he went for a time on a whaling voyage. Returning to Glasgow, he devoted himself to general practice until 1861, when he entered as a student at the Glasgow Eye Infirmary. Here, at length (in 1867) he became surgeon. In 1869 he was elected Waltonian Lecturer and Lecturer on the Eye at the University, and continued both to practise and to teach until his retirement in 1900. In 1896 the degree of LL. D. was conferred upon him by the University in which he taught, and, in 1908, the order of "Commendatore of the Crown of Italy" was conferred upon him by the Italian King. He was a modest and unassuming man, but one of great firmness and pertinacity. He died suddenly, Mar. 23, 1911. His portrait in oils was presented to the Airdrie Public Library by a large number of admirers, on Nov. 3, 1911, the speech of presentation (to which the present writer is indebted for most of the facts in this sketch) being made by Dr. A. Maitland Ramsay, of Glasgow.—(T. H. S.)

Reisinger, Franz. Son of Dr. Felix Reisinger, body-physician to the last Elector of Trier, and himself a physician of note, being a well known ophthalmologist and inventor of the ophthalmo-phantome. Born at Coblenz, Germany, in 1787, he removed with his parents at the age of seven to Augsburg, and pursued his professional studies at Landshut, Würzburg and Göttingen. At the latter institution he graduated in 1814, his dissertation being "De Exercitationibus Chirotechnicis et de Constructione atque Usu Phantasmatis in Ophthalmologia." After a number of scientific journeys, he settled in Augsburg, as a general practitioner, paying, however, especial attention to diseases of the eye. In 1819 he removed to Landshut, in order to accept the chair of surgery and ophthalmology. Here he was active in very many ways, being a man of marked executive ability and great kindheartedness and benevolence. He died April 29, 1855.

Reisinger's more important ophthalmologic writings, in addition to the dissertation above-mentioned, are as follows:

1. Ueber das Wirken der Chir. Lehranstalt zu Landshut. . . . nebst einem Bericht über die Chir. Ophthalmol. Klinik und Polikinik. (Sulzbach, 1823.)

2. Hyoscyamin und Atropin. (*Salzburger Med. Chir. Zeitung,* 1825, Vol. I, p. 237 ff.)

3. Bayerische Annalen der Chir. Augenheilkunde und Geburtshilfe. (Vol. I, Sulzbach, 1828.)—(T. H. S.)

Rekoss disk. See p. 8967, Vol. XII of this *Encyclopedia.*

Relapsing herpes of the cornea. See p. 3440, Vol. V of this *Encyclopedia.*

Relative dispersion. In optics, the ratio between the mean dispersion ($n_F - n_C$) and the difference between the mean index of refraction (n_D) of the substance and the index of refraction of air ($n = 1$), that is: $\frac{n_F - n_C}{n_D - 1}$, where D, F and C are the lines of the spectrum. See, also, **Chromatic dispersion.**—(C. F. P.)

Relative hemianopsia. That form of anopsia in which the visual loss is not complete.

Relative range of accommodation. See **Accommodation, Relative range of,** p. 52, Vol. I of this *Encyclopedia.*

Releveur à manche. (F.) Lid elevator.

Releveur pour enfant. (F.) A lid elevator of a size and shape suitable for children's eyes.

Relumine. To light anew.

Remnants, Fetal. See **Congenital anomalies of the eye,** p. 2776, Vol. IV, as well as **Heredity in ophthalmology,** p. 5812, Vol. VIII of this *Encyclopedia.*

Remy's diploscope. See p. 4011, Vol. VI of this *Encyclopedia.*

Renaglandin. One of the succedanea of adrenaline and used like it as a hemostatic and vaso-constrictor.

Reneal choked disc. A term suggested by Wm. F. Hardy (*Ophthalmology,* Dec., 1916) in contending that optic neuritis and choked disc are etiologically distinct entities; (2) that the assumption of a manifold pathogenesis of choked disc is probably incorrect; (3) that papilledema is primarily of mechanical origin, all the concomitant phenomena being accountable for on that basis. (4) That the inability always clinically to distinguish between the two conditions does not necessarily imply a common origin or identical process; (5) that optic neuritis is primarily and essentially an inflammatory process. Choked disc is primarily and essentially an edema and lymph stasis, the resultant of increased intracranial tension. (6) Renal choked disc exemplifies both processes, each with its separate pathogenesis, showing a lymph stasis with edema and also inflammatory changes.

Rendle, Edmund M. Russel. A well known English ophthalmologist. Born in 1832, he was from 1866 to 1893 surgeon to the Plymouth Eye Infirmary. He retired from practice in 1899, and his death occurred in 1909 in the spring or early summer.—(T. H. S.)

Renforcation. (F.) Intensifier.

Renoform. One of the numerous fluid extract succedanea of adrenaline hydrochloride. It is an efficient vaso-constrictor and considerably cheaper than adrenaline. Goldschmidt (*Therapie der Gegenwart,* July, 1903) recommends it as possessing all the good qualities of adrenaline.

Renostyptin. Like suprarenine and adrenaline this derivative of the suprarenal capsule is employed as a hemostatic and vaso-constrictor. It probably possesses no particular advantage over suprarenaline or similar adrenal extracts.

Renversement of a corneal flap. See **Gayet's transplantation**, p. 5347, Vol. VII of this *Encyclopedia.*

Repositor. An instrument used for returning a displaced organ to its normal position.

The *iris* repositor or spatula is made of metal, tortoise-shell or hard rubber. Generally the blade is 8 mm. long and 2 mm. wide, with the extremity blunt, to avoid wounding the iris. See p. 6639, Vol. IX of this *Encyclopedia.*

Reptiles, Eyes of. The average eye of reptiles closely resembles, morphologically, the same organ in birds. For instance, it has a cartilaginous layer with anterior bony plates in the sclerotic; also a vascular, pigmented pecten projecting well into the vitreous. It is furnished both with lachrymal and Harderian glands; the muscular fibres of the iris are striated, and there are two well-developed eyelids and a functionating, nictitating membrane. Moreover, in many of the Geckos the third lid passes over the cornea in winking, but there is a transparent area in the nictitating membrane to admit light. In snakes this arrangement seems to be permanent, the membrane being immovable and fixed upon the cornea. Chameleons have but one lid with a central opening opposite the pupil.

The median or pineal eye is best represented in certain lizards. Parker and Haswell point out that it is sometimes formed from the distal end of the epiphysial diverticulum. It takes the form of a rounded capsule, the outer or anterior portion of the wall of which is a lens formed of elongated cells, while its posterior part is retinal. The retina has an outer layer of nerve fibres and an inner collection of rod-like visual elements, thus giving the picture of the invertebrate eye. See, also, **Comparative ophthalmology,** especially p. 2565, Vol. IV of this *Encyclopedia.*

Réseau. (F.) Network.

Resection. A cutting out. Exsection of part or the whole of an organ.

Reserve accommodation. As Landolt has shown, from one-fourth to one-third of the accommodative power must be held in reserve if long-continued eye work is to be done without producing asthenopic or other symptoms.

Residual dispersion. In *optics,* the color-error remaining after an optical system has been designed so as to be achromatic with respect to one pair of colors, and which is due to the so-called "irrationality of dispersion." See, also, **Chromatic dispersion,** p. 2192. Vol. III of this *Encyclopedia.*—(C. F. P.)

Resin. In ancient Greco-Roman times the resins of various trees were used as medicaments in ophthalmology. Those from the cherry tree, the plum, and the various evergreen trees were in highest favor. The resin itself was sometimes used, sometimes the soot produced by burning it. The soot was also employed as a lid cosmetic, being then called "kalliblepharon."—(T. H. S.)

Resina empyreumatica liquida. See **Tar.**

Resolvent collyrium. A collyrium made by dissolving 1 part of lead acetate in 96 parts of water; or by mixing 3 parts of lead acetate dissolved in water with 1 part of quince mucilage.

Resolving power. The numerical expression of the power of an optical system to differentiate two or more lines or points.

Resorb. (To) re-absorb.

Resorbent. Adapted to absorb again that which had been given out.

Resorcin. RESORCINOL, U. S. METADIOXY-BENZENE. $C_6H_4(OH)_2$. This is diatomic phenol and occurs as white (reddish on exposure to air) crystals with a disagreeable, sweetish taste, and a faint, peculiar odor. It is slightly soluble in water and alcohol; readily soluble in ether and glycerine. It is a local anesthetic and antiseptic and used as a dermal application in 2 to 4 per cent. solutions in glycerine and water.

Resorcin has been extolled as a remedy for blepharo-conjunctivitis in 1 per cent. mixtures with lard, petrolatum, cold cream and other excipients, but this combination does not possess any particular advantage over other and less irritating applications.

In the simple, hypertrophic form of marginal blepharitis Gradle advises the following resorcin mixture with sulphur, to be applied to the lid margins at night: ℞ Resorcin, Lactis sulphur. āā, 1.00 (gr. xv), Vaselini, 4.00 (ʒj).

Percy Friedenberg uses the following mixture, after cleansing the lid edges, in chronic blepharitis: ℞ Ichthyol, 0.20, Resorcin, 0.30, Lanolin, 5.00, Ungt. aquæ rosæ, 5.00.

As a mild astringent, Lawson (Text-book, p. 538) gives the following collyrium; ℞ Resorcin, gr. xxxvi, Aquæ dest., fl. ℥viii.

Elze (*Wochenschrift f. Ther. u. Hygiene des Auges,* 1909) used resorcin in the treatment of early cataract. He applied a half- to one-per cent. ointment in yellow vaseline. This is applied to the conjunctiva once a day for two or three weeks, with, he claims, "far-reaching results." A visual acuity of J 16 has been improved to J 7, and of J 9 to J 3, the improvement being "permanent."

He states that striæ that are once definitively formed are not altered by the treatment, but that the intervening portions of the lens are cleared, hence it is important to make an early diagnosis, and initiate the treatment as early as possible.

Elze was led to use resorcin for this purpose by the effect of certain fibrolysins in promoting the absorption of the fibrous or fibrinous nodules of rheumatism.

He states that it is quite possible to obtain on the average an improvement in visual acuity of from three to four degrees of Jæger types, but that it is useless to attempt a cure when the vision has fallen below Jæger 12 or 14. In all cases the glasses giving the best vision should be ascertained and worn by the patient.

From several years' experience Paul Knapp (*Prac. Med. Series*, Eye, p. 36, 1912) recommends resorcin as an addition to the drugs generally in use for the chronic forms of conjunctivitis. He found its action as favorable as that of zinc, in some cases even superior to it, if instilled in from 2 to 3 per cent. solutions, two or three times a day. Aqueous solutions gradually turn brown if exposed to air, but the addition of boric acid preserves them for a long time.

Resorcinolphthalein anhydride. See **Fluorescein,** p. 5228, Vol. VII of this *Encyclopedia.*

Resorcinol, U. S. See **Resorcin.**

Respiratory movements and their influence on the eye. It is very widely assumed that in normal breathing, every inspiration effects a slight dilatation, and every expiration a slight contraction of the pupil. Entoptic observation, however, shows that such variations in the size of the pupil, even after careful exclusion of all external stimulatory variations, do not coincide in their time with the respiratory rhythm. Neither forced breathing, slow breathing, nor absolute inhibition for a number of seconds, shows anything like a regular influence on the activity of the pupil. Pathological respiration, on the other hand, does seem to wield some influence, since in cases of dyspnea, which leads to cyanosis, especially in cases of sudden lack of breath, a widening of the pupils is shown. In incipient asphyxia, the pupil is contracted, and then dilated; resuming, after death has set in, about the average width. In asphyxiation there appear also hemorrhages of the conjunctiva, the retina, and the skin of the lid. In connection with the Cheyne-Stokes phenomenon there is often a contraction of the pupils, while the light reaction is not distinct. With the cyclic increase in the respiratory movements the pupils dilate again. With the contraction of the pupils there is also observed in these phenomena a nystagmus-like movement of the eye. See p. 2038, Vol. III of this *Encyclopedia,* also under **Pupil.**

Hemorrhages, accompanying sneezing, violent blowing of the nose, or coughing (see p. 5799, Vol. VIII of this *Encyclopedia*) may occur in all the vascular tissues of the eye, most frequently in the conjunctiva, but also in the lids, the anterior chamber, and even in the retina. Anterior-chamber hemorrhages, occasionally produced by violent expirations following operations, usually originate in the wound.

Luxation of the eyeball (p. 7556, Vol. X of this *Encyclopedia*) has been observed to follow violent blowing of the nose; especially has this accident occurred in Basedow's disease. Violent and repeated sneezing during a meal may force particles of food not only into the nose, but into the tear-ducts themselves. Emphysema of the conjunctiva and eyelids (see p. 4301, Vol. VI of this *Encyclopedia*) may be caused by the entrance of air under the skin through the tear-ducts, especially after rupture of the duct. Hemorrhages into the orbit, or retrobulbar bleeding into the tissues of the optic nerve may be caused by violent coughing, especially if there exists some previous disturbance of the circulation. In cases of disease of the blood-vessel walls, violent coughing may give rise to rupture of the carotid in the sinus cavernosus, and through this to pulsating exophthalmia. Finally, vision may suffer from cerebral hemorrhages, caused by violent coughing or blowing of the nose (Schwarz, *Encyklop. der Augenhlk.*, p. 57).

Restitutio ad integrum. Complete return to health.

Restoration of ocular organs. RECONSTRUCTION OF THE EYE. In addition to the matter given under **Plastics**, p. 10255, Vol. XIII; **Blepharoplasty,** p. 1052, Vol. II of this *Encyclopedia,* and similar captions, mention may be made of an additional method—one of many.

Koellner (*Muench. med. Woch.,* October 10, 1911), describes restoration of the lower lid by means of a conjunctival (tarsal) flap from the upper lid.

A rectangular flap including conjunctiva and tarsus (in size corresponding to or slightly wider than the defect) is dissected from the posterior surface of the everted lid, the lower border running parallel to and 2 mm. distant from the lid margin. This side forms the free margin of the flap, which is then drawn down over the eye and inserted into the defect in the lower lid and fastened by sutures, the upper retrotarsal conjunctiva becoming the new conjunctival covering for the upper lid. Pedicled skin flaps (preferably Thiersch grafts) form the external covering of the new lid. Re-enforcing sutures may be necessary to keep the lids approximated and prevent the sutures from tearing out. An ointment dressing is applied and both eyes kept bandaged for 24 hours. On the seventh or eighth day the conjunctival bridge is divided and redundant conjunctival tissue trimmed away.

Retardation. (a) A negative acceleration, or continuous decrease of velocity. (b) The distance by which one soniferous or luminiferous wave is behind another.

Retention cysts. These are generally found in the iris. See p. 3676, Vol. V of this *Encyclopedia.*

Retiary. Reticular. Reticulate. Reticulated. Net-like; netted.

Reticle. Reticule. Reticulum. A network of ruled lines or fibers such as is used in many optical micrometers.

Reticular keratitis. See p. 6809, Vol. IX of this *Encyclopedia.*

Reticular layer of the iris. The second layer of the iris from before backward.

Reticular opacities of the cornea. See **Lattice-shaped opacity of the cornea,** p. 3382, Vol. V of this *Encyclopedia.*

Réticule. (F.) Crosswires.

Retina. This, the inner tunic and perceptive layer—the "sensitive plate"—of the eyeball, is formed by the expansion of the optic nerve and lies between the choroid and vitreous. Its gross anatomy is discussed and illustrated on p. 390, Vol. I, and its histology similarly treated on p. 5959, Vol. VIII of this *Encyclopedia.*

The same membrane as it appears in the lower animals is described under **Comparative ophthalmology,** especially on p. 2673, Vol. IV. See, also, **Macula lutea,** p. 7572, Vol. X; **Fundus oculi,** p. 5315, Vol. VII; as well as **Psychology of the eye.**

The *anomalies and diseases of the retina* will be considered under various other headings of this work, especially following this head.

Retina, Abscess of the. Retinal suppuration. This is never a primary condition but always associated with such processes as panophtholmitis, suppurative choroiditis or similar infection. See p. 9232, Vol. XII of this *Encyclopedia.*

Retina, Actinomycosis of the. A case of this extremely rare infection (see p. 84, Vol. I of this *Encyclopedia*) is described by Lewin and Guillery (*Giften auf das Auge,* II, p. 654).

Retina, Albinism of the. Absence of retinal pigment. See p. 204, Vol. I, and p. 2950, Vol. IV of this *Encyclopedia.*

Retina, Anemia of the. Anemia of the retina is simply a local expression of general anemia, and may be exceedingly difficult of diagnosis. In fact, in the absence of a proper examination of the blood, diagnosis with the ophthalmoscope may be impossible.

In some cases, however, the fundus changes are so marked as to be considered almost pathognomonic. Thus, in chlorosis, pernicious anemia, and leucocythemia the fundus often shows marked changes. The whole fundus is paler than under normal conditions; the optic-nerve head is lustreless and grayish, and neuroretinitis is common. There is a greater tendency to inflammation of the nerve-head and retina in chlorosis than in pernicious anemia, while the tendency to retinal hemorrhage is less (Stephen Mackenzie). Posey states that in initial anemia from loss of quantity of blood there are seldom ocular changes unless some other factor than loss of blood exists. In cases of chlorosis and pernicious anemia observed by Oliver there were marked changes: the optic disc was of a yellowish-white color, with hazy and in places indiscernible edges; the fibre-layer of the retina was opaque, thickened, and striated; the vessels were pallid and showed opacification of their lymph-sheaths and pronounced neuroretinitis was present. Visual acuity was reduced and the fields of vision were contracted. Blood-examinations showed a great diminution of red blood-corpuscles and hemoglobin. See, also, **Retina, Ischemia of the**; as well as **Chlorosis, Ocular symptoms of**, p. 2068, Vol. III of this *Encyclopedia.*—(J. M. B.)

Retina, Anesthesia of the. See **Hysterical amblyopia**, p. 299, Vol. I of this *Encyclopedia.*

Retina, Aneurism of central artery of. See p. 462, Vol. I of this *Encyclopedia;* also, **Retina, Miliary aneurysm of the.**

Retina, Angioglioma of the. Ginsberg and Spiro (*Ophthal. Year-Book*, p. 325, 1913) have described a case which from microscopic study they called angioglioma with only local malignancy. In May, 1905, at the age of 7 years, the patient, a boy, was carefully examined and nothing abnormal detected. In January, 1906, he complained of fluttering before the left eye. Slight swelling and loss of definition at the temporal margin of the left disc were found, and in the right eye there was a rose-tinted mass about one-half the size of the disc and 5 disc diameters below it. In the left eye the swelling increased until it appeared as a growth covering the nerve head and measuring 3 disc diameters in width and 4 in height. In 1908 the retina was detached, in 1910 there were attacks of glaucoma, and in 1912 the eye was enucleated. In the temporal portion of the retina was a tumor measuring 2½ by 1½ mm. Its predominant features were numerous blood vessels, and glial tissue rich in cells. There was a second smaller nodule of the same character. It is suggested that the case may have some relationship with the angiomatosis (q. v.) of Von Hippel and others.

Retina, Angioid streaks in the. See p. 465, Vol. I of this *Encyclopedia.*

George Coats (*Oph. Review*, p. 310, Oct., 1913) in reviewing the essay of H. Bayer (*Klin. Monatsbl. f. Augenh.*, Vol. LI, p. 766, 1913) remarks that to our knowledge of these peculiar formations pathological anatomy has given but little aid, Lister attributing them to a formation of new vessels beneath, or in outer layers of the retina, Magitot stating categorically that new vessels are absent, and ascribing the appearances to regressive changes in old hemorrhage. Since no ophthalmoscopic examination had been possible in his cases, Lister admits that his explanation is no more than a suggestion; perhaps the finding of new vessels in eyes blind from irido-cyclitis is not of very great significance. In Magitot's case an ophthalmoscopic examination had been made, but not for a year before death, and as the patient died of apoplexy it is very possible that much of the retinal hemorrhage had occurred during the intervening period; moreover, the eyes were not fixed for 24 hours after death, and Bayer, having examined a preparation from Magitot's case, disagrees with his conclusions and believes that the ophthalmoscopic appearances were due to certain small collections of pigmented cells.

Pathological results being thus equivocal we are left in the airy region of speculation. It is certain that hemorrhage, whether as a cause, effect, or concomitant of the condition, is not infrequently observed, and it has been asserted that a linear hemorrhage has been seen to transform itself into an angioid streak. Bayer concludes that the lesion is in the outer layers of the retina, and that its cause is quite obscure, but that it does not depend on any constitutional condition and is not senile.

To the reviewer it appeared that there was much to be said in favor of the view that angioid streaks are a superficial choroidal, and not a retinal condition. Disease of the choroid seems to be present in nearly every case, taking the form sometimes of slight superficial degeneration, disturbance of pigment, colloid bodies, etc., but sometimes of considerable areas of organizing material, often mixed with hemorrhage, and apparently situated on the surface of the choroid; on the other hand, disease unequivocally confined to the retina seems to be rarely observed. The presence of pigment is in itself a point in favor of a choroidal origin, for blood pigmentation is seldom so permanent; and the hemorrhage when present is usually deep, and with a flat, rather indefinite appearance, suggesting a localization on, or in, the superficial layers of the choroid.

Against the view that the streaks are due simply to regressive changes in an old hemorrhage their long linear course and method of branching may be urged; moreover, as Bayer points out, a purely hemorrhagic origin does not account for the wholly irregular transition from pigmented (presumably old) to unpigmented (presumably recent) areas. Against the view that they are nothing but new vessels may be cited the great variability in their appearance not only in different cases, but in different parts of the same fundus; in some instances they are deep-brown or almost black, in others they have rather a crimson-lake or dark brown-red color, and in others again their resemblance to vessels is very great. Moreover their peculiar irregularities of calibre, their manner of tapering and expanding, the fact that their lateral limits are sometimes not linear but slightly frayed or irregular, the observation that they may be apparently interrupted by white areas beyond which their course is continued, the abrupt way in which they seem to begin and end without evident connection with choroidal or retinal vessels—these are points which appear to show that something more is in question than a simple new formation of vascular channels.

Their appearance, to the reviewer, suggests fine vessels, patent or occluded, lying on the surface of the choroid and partially or completely concealed by a heaping up of pigment along their course. Such vessels are sometimes found pathologically embedded in a small quantity of fibrous tissue and situated between the membrane of Bruch and the pigment epithelium; they have points of resemblance to the new vessels which may form on the surface of the iris, and probably have the same tendency to run athwart the vascular system of the part. If such small twigs ran into the choroidal vessels under their covering of pigment their apparently abrupt commencement and termination, and their lack of connection with the retinal vessels would be explained. The hemorrhage may be due to the rupture of such vessels, but it is possible also that it may have a more primary significance, and that its organization and absorption may be causal factors in the development of the vessels.

All this, however, is no more than a guess. The solution of the question must come from the pathological anatomist. If it be true as is stated by Walser that the streaks can be rendered entoptically visible, then the lesion must be in front of the rods and cones, but the observation is obviously liable to error in any but a very intelligent patient, and it is difficult to reconcile it with Walser's further statement that the lesion is situated in the hexagonal pigment layer of neuro-epithelium.

William Zentmayer (*Trans. Coll. Phys., Phila.*, Oct. 16, 1913) has also presented a case of angioid streaks in the retina. So far as possible to judge by comparison of the fundi at the present time with the colored reproductions made five years ago, the only changes that have occurred are a complete absorption of the hemorrhage that was present in the macular region, an apparent increase in peripheral chorioretinitis, and a loss of transparency of the retina throughout, which has rendered the streaks less conspicuous. The streaks themselves show no alteration. Zentmayer does not accept the view that these streaks are the result of metamorphosed blood, but inclines to the belief that they are new-formed vessels.

de Schweinitz referred to the case-records of two patients with angioid streaks in the retina that he had published, these patients being brothers, and to the fact that he had been able to keep one of the patients under observation for about a year without noting any decided change in the fundus lesions. An interesting appearance in the eye-ground was a large hemorrhagic area in the macular region from which a number of angioid streaks appeared to diverge, very much as streams might from a pond, and this had led him at the time to accept the theory that these angioid streaks might represent a metamorphosis of hemorrhages diffused in a linear manner through the deeper layers of the retina, as Ward Holden had suggested. He was not then acquainted with Lister's observations, which certainly represent a more satisfactory explanation of the condition.

Retina, Angiomatosis of the. Angioma of the retina. Any form of blood-vessel tumor is of rare occurrence in the retina. Von Hippel (Graefe's *Archiv für Ophthalmologie,* LXXIX, ii, p. 350, 1912) discusses one form of this condition, reviewed by Coats (*Oph. Review,* p. 347, Nov., 1912). It is characterized by the enormous enlargement of an artery and vein in one or more regions of the fundus, the swollen vessels disappearing in the periphery into a red or yellow area. The two vessels are usually strikingly similar in color. Hemorrhages and exudation are frequently present in the retina, and the disease usually progresses very slowly under observation. The first case was described by Fuchs, and pathological examinations have been made by Treacher Collins and Czermak.

In von Hippel's case the eye was lost from secondary glaucoma 16 years after the onset of the disease. In the meantime the retina had become detached and displaced into the lower temporal quadrant, so that no exact orientation or comparison with the former ophthalmoscopic pictures was possible. A short distance from the papilla on the temporal side the retina ran into a tumor-like mass, which lined the interior of the globe, and consisted exclusively of coils of vessels supported by neuroglial tissue, much proliferated in places. These vessels were mostly of capillary size, and it was difficult to demonstrate that the main retinal vessels broke up to form them; rather the larger vessels seemed to run through the angiomatous tissue. More anteriorly isolated glomerulus-like nodules of similar angiomatous structure occurred in the inner layers of the retina, and projected into the vitreous. Hemorrhage was present in the subchoroidal space as well as in the retina near the papilla and anteriorly. Some of the vessels showed endarteritis, endophlebitis and thrombosis. The central vessels were patent, and apart from the presence of a few leucocytes in their walls, were normal.

Masses of cicatricial tissue and bone were found on the surface of the choroid, and in one place a large retinal artery had acquired a connection with the choroidal vessels, which were gigantically enlarged. The other changes were those of iritis and secondary glaucoma.

The author was able to compare his case with unpublished drawings and photographs of Czermak's, in whose case the choroid was not so much involved. In the retina well-defined egg-shaped and round nodules occurred, within which an artery and vein broke up to form more or less close-textured networks of capillary loops. Many of the vessels were thick-walled. There were signs of iritis and secondary cataract.

There can be no doubt of the essential similarity of the disease in the cases of Treacher Collins, Czermak and v. Hippel, and the latter seems to be fully justified in considering the process to be fundamentally a formation of vascular tumors—an angiomatosis—of the retina. The enlargement of vessels is probably secondary to this vascular new-formation, and the similarity of color in the artery and vein is most likely attributable to an undue patency of communication between them through the enlarged capillaries. Vascular disease seems to be present relatively early. Retinal exudation, detachment and hemorrhage are probably secondary.

v. Hippel discusses the relationship of the disease with certain cases described by the reviewer under the title "retinal disease with massive exudation." He holds that the two conditions are essentially different, although the cause of the white exudation in the fundus may be the same in each—deep retinal or subretinal hemorrhage. The pathological examinations now available are probably sufficient to bear out this opinion, which is indeed practically the same as that expressed by the reviewer, who pointed out that there were no cases transitional between the present disease and his other cases, and who accepted the condition as "a genuine simple tumor of the retina."

Additional cases are abstracted in the *Ophthalmic Year-Book*, 1916. Emanuel examined the eye of a boy of 2 years removed on account of suspected glioma. In the retina hemorrhages and exudation were found, together with cysts, colloid and hyaline degeneration. A homogeneous substance was deposited in the subretinal space and outer retinal layers. In the inner layers of the retina was a tremendous accumulation of large vessels. The case is declared to be one of angiomatosis and not one of exudative retinitis (Coats) because of the just mentioned vascular changes, and because in the ciliary body a tumor-like proliferation of blood vessels, mostly capillaries, was found.

Wada's patient, a man of 24 years, whose vision failed within four months, showed a light, dirty-gray fundus with red areas in the lower temporal periphery surrounded by a grayish-white zone. An artery and vein looking very much alike, united in this area. Later a new gray area with a red spot in the center developed.

Of the cases reported by Meller, Vossius (2), Stern and Banc the last was seen but once, when the man was 32. Defective vision had been noticed for four and three years, respectively; but the sketch of the ophthalmoscopic appearances made at the time showed them to be perfectly characteristic. Vossius' first case showed the right eye with vision reduced to counting fingers at 2 or 3 meters, while the left still had normal vision, but with characteristic changes in the ocular fundus. The second case had only recently noticed impairment of vision in her better eye, the other having been injured in childhood. The case reported by Stern was that of a man of 21, who had noticed impairment of vision in the left eye for seven years, followed in a year and a half by pain, and later complete blindness from shrinking of the globe. Recently he had noticed that the right eye was weaker and vision reduced to ⅓. The ophthalmoscope showed the characteristic retinal changes. Meller's patient, a youth of 20, had noticed impairment of his left eye seven years before. It became blind in a year, but without pain. It now had a shrunken, calcareous lens. In the right eye vision was reduced to 6/60, and the usual vascular changes were noted. This patient gave a tuberculin reaction.

In discussing his case Meller puts forward the view that the thickening of the retina is due to non-inflammatory proliferation of the glial tissue, which is the primary change, and that the alterations in the vessels are secondary to this; in oppositon to the view of von Hippel that the proliferation of the glia is secondary to the vascular changes. In harmony with his own view, Meller suggests that the proper name for the condition is not ''angiomatosis'' of the retina, but ''gliosis retinæ diffusa teleangiectodes.'' Darier, writing on retinal angiomatosis, reproduces the description of the case which he first reported in 1890. Of the two cases reported by Pooley as angioma of the retinal vessels, and Grimsdale's case of exudation of the retina with dilated vessels, the details given in the case histories are not sufficent to determine certainly whether these are cases of angiomatosis. See, also, **Retina, Juvenile diseases of the.**

Retina, Angiosclerosis of the. ARTERIOSCLEROSIS OF THE RETINA. RETINAL SCLEROSIS. See p. 614, Vol. I of this *Encyclopedia.* In addition, attention is drawn to the following.

Deyl (*Wien. Klin. Rundschau,* Aug. 25, 1912) remarks that if the pressure that must be applied to the eyeball to bring about normal pulsation in the papillary arteries, is to be increased, the wall of the blood-vessel may be considered more rigid in consistence, but if pulsation in the retinal arteries can be produced by lighter pressure than normally, then the blood pressure is either diminished or the structure of the vessel wall is pathologically changed.

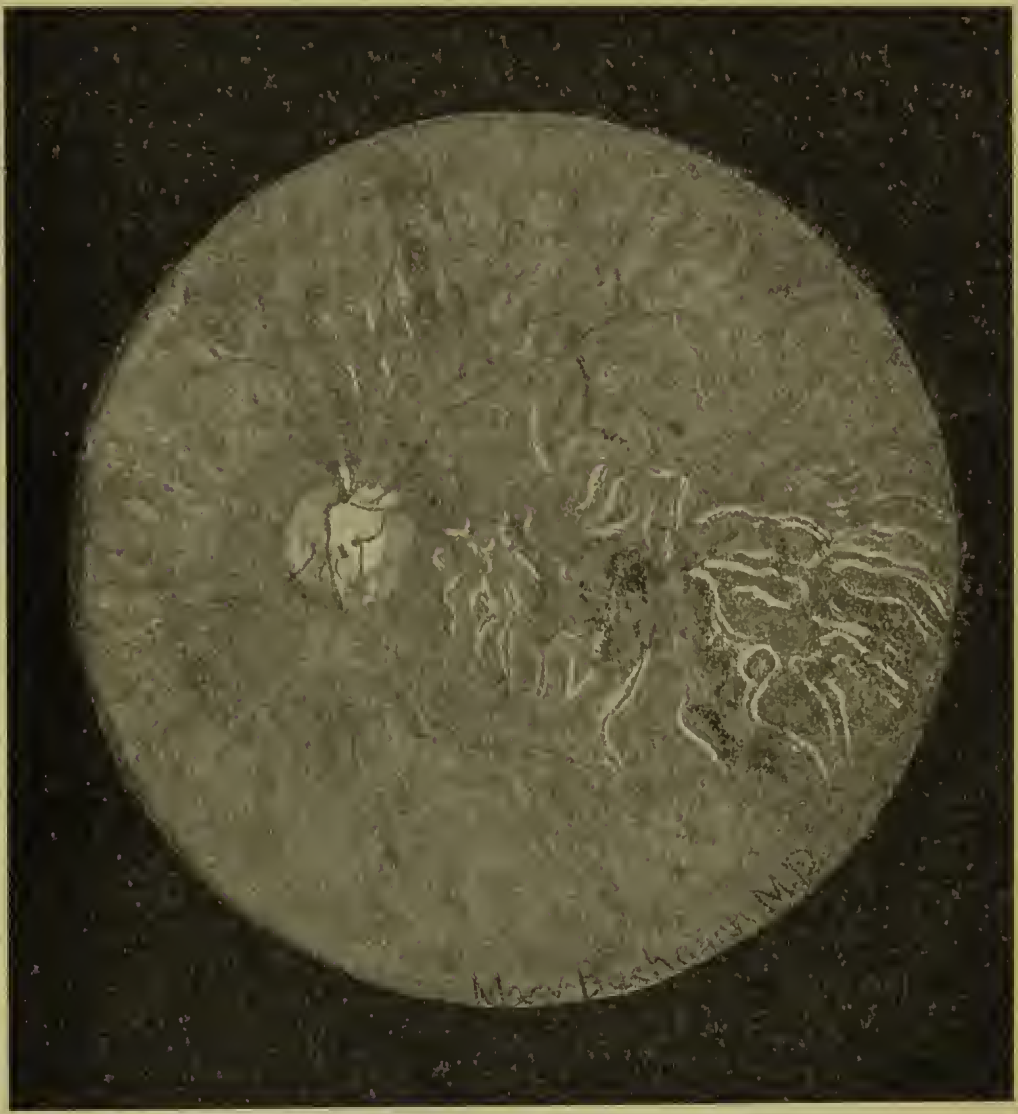
The close relationship between retinal angiosclerosis and cerebral angiosclerosis makes arterial hypertension in the eye an important diagnostic symptom in various cases of paralysis of the eye muscles, in intraocular neuritis and in choked disc. These pathological changes can be produced by serious cerebral disease or by arteriosclerosis.

In cases of hemorrhagic glaucoma, where transillumination cannot be applied, the differential diagnosis between hemorrhagic glaucoma and intraocular tumor can be made by examining the arterial tension in the other eye.

A review of R. Foster Moore's essay (*Trans. Ophth. Soc. U. K.,* Vol. 36, p. 319, 1916) is published in the *Br. Jour. of Ophthalm.,* p. 253, Apr., 1917.

Following the teaching of Gull and Sutton (1872), Moore regards the primary change in arterio-sclerosis as a general disease, commencing in the arterioles and smaller arteries and producing secondarily increased resistance to the onward passage of the blood, causing the tissues to suffer in their nutrition. This leads to an increase in the force of the heart-beat, and hypertrophy, together with increased pressure in the large arteries, follows.

In the present communication the author adduces reasons for believing that, at any rate in some cases of arterio-sclerosis, the pressure in the intra-ocular vessels so far from being raised, may be actually less than normal. It was shown by Gull and Sutton that so-called "arterio-capillary fibrosis" affected the vessels of the pia mater, kidney, spleen, lungs, etc. But if Moore's suggestion with regard to the pressure in the small vessels of the eye can be substantiated, it is also doubtless true of the other vessels. It is pointed out that the conditions in the eye can be investigated upon lines that are not available in other parts of the body, owing to the ophthalmoscope and Schiötz tonometer. Normally, the blood enters the eyeball through the central retinal and ciliary arteries at a pressure of 100 mm. of mercury (Leonard Hill), and is opposed by an intra-ocular pressure of about 20 mm. of mercury. Pulsation is not seen in the retinal artery, although if the intraocular pressure be raised by finger pressure, it will be found that when the intra-ocular pressure is raised by that means to a point in excess of the diastolic arterial pressure, blood enters only during systole, and the central artery, as observed with the ophthalmoscope, pulsates. Moore points out that in some cases of arterio-sclerosis, with very high pressures in the larger arteries, a degree of pressure with the finger is sufficient to



Diffuse Sclerosis of the Retinal and Choroidal Vessels (Reber).

produce pulsation, which is less than that required in a healthy patient. The inference is that in such cases the diastolic pressure in the retinal artery is less than that of a patient with a normal blood-pressure. There are special difficulties in the way of estimating the systolic pressure in a similar manner. Evidence from a consideration of variations in the intra-ocular pressure bears upon the mean pressure in the intra-ocular vessels, but does not differentiate the systolic from the diastolic. Its bearing, also, is upon the pressure in the ciliary vessels, since it is upon them that the intra-ocular pressure depends.

In connection with the conclusion that the mean pressure in the ciliary arterioles and capillaries is not raised as a result of a very high pressure in the large vessels, the following additional observations are of some importance.—The pulse wave from inside the eyeball is transmitted to the lever of the Schiötz tonometer. In the presence of severe arterio-sclerosis the lever shows less amplitude of movement, and in a few cases no pulse is to be seen. Sixty-one patients were examined from this point of view, and the average systolic blood-pressure of the three groups into which they were divided was afterwards worked out. The figures were as follows:

Pulse movement of lever.	Number of patients.	Average systolic blood-pressure.
Well seen	25	168 mm. Hg.
Poorly seen	29	190 mm. Hg.
Not seen at all	7	225 mm. Hg.

From the foregoing figures, it will be seen that the amplitude of the pulse movement is inversely proportional to the degree of arterio-sclerosis as judged by the blood-pressure, and allowing for the fact that local changes in the vessels would tend to prevent the transmission of the pulse to the other contents of the eyeball, the observations are at least compatible with the view that the pressure in the ocular vessels is not raised.

If the ocular vessels are the subject of sclerosis and the blood-pressure within them is not compensatorily raised, the retinal functions are likely to be impaired, and this may be brought about in two chief ways: (1) there may be thrombosis in the artery; (2) there may be a gradual impairment due to a relative starvation of the tissues.

Moore watched five belonging to the first group of cases for several years. He notes that all the patients were the subject of marked arterio-sclerosis, with obvious disease of the retinal vessels. The onset usually occurred at night. He has recently seen a man who complained of defect of sight as soon as he recovered from an anesthetic, given for the performance of a somewhat severe operation. The immediate cause of the thrombosis was doubtless the lowered blood-pressure during somewhat prolonged anesthesia. As regards the second group of cases, deterioration of sight is gradual, and such patients may develop thrombosis of the artery.

It appears probable that the only sites in the body other than the eye in which thrombosis of a vessel of the size of the retinal artery would give rise to immediately noticeable symptoms are the heart, the internal ear, and parts of the central nervous system.

Moore, in conclusion, suggests that vigorous measures directed towards the lowering of blood pressure, whilst they may relieve a failing heart or avert a cerebral hemorrhage, are liable to act inimically towards the nutrition of the tissues of the body, by further reducing the already curtailed blood supply, and making the occurrence of thrombosis in the small vessels more probable.

Arnold Knapp (*Medical Record,* May 29, 1915) summarizes the commonly received beliefs regarding the prognostic significance of sclerotic changes in the retinal vessels as follows:

1. Distinct arteriosclerotic changes in the retinal vessels indicate a similar state in the cerebral vessels, but not the reverse.
2. Slight changes are suggestive and of importance if associated with other symptoms of arteriosclerosis.
3. "Silver wire" retinal arteries and retinal hemorrhages, if no disturbance of the blood constituents is present, are each indicative of raised pressure.
4. In nephritis and diabetes there are changes in the retina due to arteriosclerosis which are independent of and give a different prognosis from the usual albuminuric and diabetic retinitis.
5. Syphilitic disease of the retinal vessels has no general prognostic significance; thrombosis of the central vein is in more than one half of the cases purely a local lesion.
6. Temporary obscurations of vision in patients with arteriosclerotic changes of the retinal vessels are of grave significance for sight.

Retina, Angiosarcoma of the. An example of this rare tumor was reported by Cyril Walker (*Trans. Oph. Soc. Un. Kgdom.,* April, 1915). The patient, æt. 4 years, was seen on November 11th, 1914. Eight months before there was said to have been a film over the right eye; no pain or redness. It disappeared in about six weeks. In June and September there was some pain in the eye, but the boy had regularly attended school to the end of October. The right eye was seen to be the seat of a brownish-yellow hypopyon. There was no ophthalmoscopic reflex; the tension was normal, and the pupil dilated well with atropine. There was doubtful perception of light. Ten days later the eye became red and tender, and there was some continuous pain; the tension was + 1. The contents of the anterior chamber were evacuated, and Walker Hall reported that the material was probably sarcomatous. The eye was accordingly excised, and submitted to the same authority. Early in December some 3 inches of the stump of the optic nerve was removed, with a mass of tissue surrounding it. Pathological examination showed that recurrence had commenced in the stump of the nerve and the surrounding tissues, but there was a small margin of healthy tissue. Recurrence took place within a fortnight of the second operation, and then the mass had attained the size of a cocoanut. The boy's mental condition was not affected, and there had been no metastasis. The specimen showed that the ciliary region was not invaded.

Retina, Anomalies of the. See **Congenital anomalies of the eye**, p. 2921, Vol. IV of this *Encyclopedia.*

Congenital absence of the arteria centralis retinæ is reported by R. I. Lloyd (*Jour. Ophthal., Otol. and Laryngol.,* August, 1915) in the eye of a man who had divergent squint of nine years' duration. There were no central vessels in the nerve head. There was, however, the usual vascular arrangement in the fundus and some large ciliary vessels. There were, also, pigment changes on the macular side of the disc and a large plaque of glistening white material which occupied the whole macular region.

Cilioretinal vessels. See p. 615, Vol. I, and p. 2242, Vol. III of this *Encyclopedia.*

Coats recognizes three varieties of anastomoses between the retinal and ciliary vessels about the nerve entrance. (a) Arterial anastomoses at the level of the sclera in connection with the circle of Zinn. (b) Both arterial and venous at the level of the choroid which run, (1) forwards to share in the vascularization of the papilla, (2) straight inwards in the substance of the nerve, (3) backwards within the pial sheath. He reports a case which illustrates all three of these plans with enlarged veins. In one eye a large trunk collecting blood from the retina passed back at the margin of the disk. In the other eye the veins from the choroid collected to form a trunk on the disk that emptied into the central retinal vein.

E. Fuchs (*Arch. f. Ophthalmol.,* XCII, 1, 1917) refers to the anomalies that Seefelder and Lindenfeld discovered in the *pars optica* and *pars ciliaris* of the retina in fetal eyes. These and further (congenital) defects often involve also the optic nerve. The writer found in the *pars optica:* 1. Small "rosettes" (ring-shaped arrangements of cells). They were situated within the inner nuclear layer, but were formed mainly by cells belonging to the outer nuclear layer. 2. Folds of the retina. These folds are not complete, i. e., there is no folding of the entire retina. The outer layers only are pushed beyond the inner layers and then bent backward. 3. One small cyst; which may have been originally a fold.

As anomalies of the *pars ciliaris* they describe: 1. A growth of the cylindrical cells beyond the inner surface of the bordering pars optica, where they expand and sometimes form minute cysts. 2. Areas within the pars plana of the ciliary body, where the ciliary epithelium contains multiple nuclei instead of one single row. These multiple nuclei are arranged in a radiated direction.

The researches of Fuchs himself refer not to fetal eyes, but to eyes that were developed. His material consisted of seven eyes, one of a child of 7, one of 8, one of 14 years; and 4 of adults. The four first mentioned had been enucleated on account of recent injuries; the others were post-mortem. First as to the *pars optica*. 1. Rosettes were not found in any of the specimens. 2. Folds of the retina were met with in case 1 and 3. These were also incomplete, consisting partly in fold-like processes of the retina with atypical structure, partly through a forward inthrust of the external layers. Fuchs found three of the first and two of the second character. 3. Of cysts only one instance was met with in case 1. It was situated in the equatorial region of the temporal half. Its structure was more complicated than the one described by Seefelder. The inner space of the cyst was slightly oval; the surrounding layers of the retina were somewhat thinned. The inner wall of the cyst was formed by cells that resembled the cells of the outer nuclear layer. Within the cavity of the cyst there were a number of large, very pale cells that resembled epithelial cells where they are packed closely. They were filled by small, irregular, slightly luminous corpuscles. Whether they were due to fatty degeneration or whether they were cells of the pigment epithelium, whose pigment had faded, is an open question. 4. Irregular growth and hypertrophy of the *pars optica* was met with in a number of the cases. In one instance the ora serrata reached farther forward than in normal eyes, the distance from the iris angle being 4 mm., temporally, and 3.3 mm., nasally, against 5.6 and 4.6 mm. in normal eyes. 5. An anomaly not mentioned by the previous authors, is a thinned portion of the retina. Fuchs found two instances of this condition. The thinning of the retina was reduced to 1/6 of its normal thickness. These areas were located in the equatorial region, along different meridians.

Pars ciliaris. 1. Hypertrophy of the cylinder cells was seen in quite a number of the cases. The findings resembled very closely those in fetal eyes. 2. Just as frequently areas were encountered where the ciliary epithelium contained more than one row of cells; in some instances four or five rows of nuclei were present. 3. As a third anomaly, Fuchs discovered the presence of "islands of atypical retina within the pars ciliaris." In 3 cases instances of this anomaly were found. They were quite numerous in each of the specimens. Fuchs gives the following description: Within a brief space the row of epithelial cells is replaced by a piece of atypical retina, which consists of a network of glia filled irregularly by nuclei. This piece of retina is considerably thicker than the ciliary epithelium. It is also larger in area and, in order to find room within the smaller vacuum of the epithelium, it is folded. It appears, therefore, like a fungus with a strangulated base.

Conus from the papilla downward. In 1913 Tertsch collected seven cases, one his own, where a downward conus had been found ophthalmoscopically and where afterwards an anatomic examination could be made. Fuchs adds to these three cases and gives a minute description of the findings. In the first case the ophthalmoscope revealed a white conus downward and slightly inward, about half as wide as the papilla. The latter itself was oval and was rounded by the conus. Distribution of the bloodvessels was somewhat irregular; excavation was of small degree. The eye was of normal size and showed a slight bulging of the sclera in the lower half. The optic nerve entered the eyeball obliquely from below upward. Within the scleral canal it made a sharp bend in the opposite direction, so that its axis formed an angle that opened downward. The sclera was of normal thickness. The nerve fibres were also normal. Below the optic nerve the sclera bulged. The anterior portion of the lower wall of the scleral canal down to the place where the choroid commences appeared ophthalmoscopically as a white conus.

In the second case the width of the conus was one-third that of the papilla. There was also a bulging of the sclera below the entrance of the optic nerve. As the latter had been severed very closely to the eyeball, nothing could be stated on the direction of its insertion. Above the edge, the scleral canal and the choroid projected below and were flattened. In case 3 the conus was the smallest. The eye was of normal size and the sclera did not bulge. The optic nerve entered the sclera vertically. Above its entrance the scleral canal and the choroid projected as in the 2nd case, but to a less degree; below they were bent and flattened.

The changes found by Fuchs are similar to those found by previous authors. The width of the conus is proportional to the degree of the changes around the optic nerve. If the latter are small, the form of the eyeball is normal; if larger, the sclera bulges below the papilla. This ectatic area of the sclera is thinned and in some instances also the choroid and the retina are found thinned. The pathologic findings in cases of conus downward are identical with those in temporal conus. Both are the result of the ectasia of the sclera. The term coloboma is therefore inappropriate. But the important difference between temporal conus and conus downward lies in the fact, that the former commences during life and is frequently progressive, whilst the latter is congenital and stationary. It is also frequently complicated by other congenital anomalies, and in nearly all the cases astigmatism and impairment of vision are present. See, also, **Conus,** p. 3286, Vol. VI of this *Encyclopedia.*

Excrescences of rudimentary retina at the edge of the papilla. These excrescences are irregular lobules, which consist of mesodermal glia, nerve fibres and elements of the retina. They grow from the optic nerve within the scleral ring or immediately after its exit. Of elements of the retina those of the nuclear layer are most frequently found, imbedded in a network of glia. Fuchs divides the cases into two categories: excrescences that grow on the inner plane of the sclera under the choroid, and excrescences that grow backward into the optic nerve, into the subdural space or into the sclera. Of the first category there are 11 cases on record, 7 of the author's: of the latter 9 cases (1 the author's). With one exception the direction of the excrescences under the choroid was a downward one. They are generally pedunculated while the excrescences backward occur in the form of a finger.

Retina, Apoplexy of the. Hemorrhage into the retina. The differentiation between retinal apoplexy and hemorrhagic retinitis rests on the presence of signs of inflammation. A hemorrhage occurring in an eye whose retina otherwise appears normal is known as retinal apoplexy; if signs of inflammation of the retina are present, the condition is called hemorrhagic retinitis.

When the hemorrhages involve the macula there is great reduction in acuity of vision. Often, however, the macula is free, the hemorrhages being numerous and situated peripherally, in which case central vision will be normal. Scotomata due to such lesions will often remain unnoticed by the patient. Ophthalmoscopically apoplexy of the retina presents red or black spots, which may vary in size, shape, and number. They contrast strongly with the bright-red fundus.

They may involve any of the retinal layers. When occurring in the nerve-fibre layer they present striate or flame-like shapes. Hemorrhages into the deeper retinal layers, or between the retina and choroid, are rounded or irregular in shape.

Apoplexy of the retina, while more common among adults of advanced age, is not infrequent in both sexes about the age of puberty. The middle-aged and elderly subjects present lesions of the heart or arteries or changes in the composition of the blood. Some of the young subjects are anemic, while others show no departure from the normal. Sudden reduction of intra-ocular tension, such as follows an iridectomy made for glaucoma, sometimes causes retinal apoplexy. Some poisons—among which are serpent virus, phosphorus, and potassium chlorate—may cause the affection. Among the constitutional conditions productive of retinal apoplexy are (according to Dimmer) septicemia, pyemia, anemia, ulcerative endocarditis, leucocythemia, menorrhagia, hematemesis, hemophilia, gout, purpura, diabetes, malaria, scurvy; certain renal, hepatic, and splenic diseases; cardiac hypertrophy with valvular stenosis, atheroma of the vessels, thrombosis of the central retinal vein, and embolism of the central artery; suffocation, compression of the carotid, and hemorrhages in the newborn. Retinal apoplexy sometimes follows large cutaneous burns. It has been observed in cases of fracture of the skull.

Hemorrhage into the retina sometimes is due to diapedesis of blood-corpuscles; in the majority of cases, however, actual rupture of an artery or a vein occurs as a result of pre-existing perivasculitis or arteriosclerosis.

The diagnosis will present no difficulties to the surgeon who is familiar with the use of the ophthalmoscope.

While in some cases, particularly in young subjects, retinal apoplexy is followed by complete absorption of the blood and restoration of vision without scotomata, the disease in many instances is a serious affection. In many cases the apoplexy recurs from time to time. There is increase of intra-ocular tension, and the condition is then known as hemorrhagic glaucoma: a most serious disease. In a period of weeks or months the retinal hemorrhages may undergo absorption, leaving choroidal and retinal changes, which may be limited to small areas or may involve the entire retina. If the hemorrhage breaks into the vitreous humor, it may leave permanent opacities and lead to proliferating retinitis. Hemorrhages into the retina in elderly persons often precede cerebral hemorrhage.

Retinal apoplexy calls for attention to the patient's general health, and, when possible, removal of the cause. Stimulants should be avoided. Rest, and the use of cholagogues and purgatives will be of value. Local bloodletting from the temple is said to be helpful. Hypodermic injections of pilocarpin and the internal use of iodid of potassium or bichlorid of mercury may be employed to stimulate absorption. In elderly persons a solution of eserin may be dropped into the eye twice a day.—(J. M. B.)

See, also, p. 5805, Vol. VIII of this *Encyclopedia;* as well as **Bright's disease,** p. 1296, Vol. II; **Albuminuria,** p. 207, Vol. I, and **Albuminuric retinitis,** p. 212, Vol. I; and similar rubrics.

Komoto examined the eyes of a boy of 17, who suffered from a hemorrhagic diathesis. Retinal and conjunctival hemorrhages accompanied fever, headache, pains in the limbs, and a petechial eruption of the skin and mucous membranes following unusual exertion. Death occurred four days later. In addition to the small hemorrhages seen during life, a large one covered the macula.

Rogers, studying of the significance of retinal hemorrhages based on 187 cases, classifies his cases as (1) retinal apoplexy; (2) simple retinitis, secondary to the former; (3) hemorrhagic retinitis, with secondary hemorrhages; (4) albuminuric retinitis; (5) diabetic retinitis, and (6) chorioretinitis. The prognosis was worst in albuminuric retinitis, 75 of the 101 patients having died. Next came hemorrhagic retinitis and diabetic retinitis, 55 and 50 per cent., respectively; 48.5 per cent. died in the first three years, and 40.9 per cent. were living at the end of ten years.

Edward Davis (*Trans. Am. Ophthal. Soc.,* Vol. xiii, pt. 1, 1913) gives a full account of a patient (man, æt. 32) suffering from recurrent retinal hemorrhage. This paper is reviewed by Beaton Hird (*Oph. Review,* p. 306, Oct., 1913). The author concludes that (1) the decided diagnostic reaction of the old tuberculin in very small doses and positive therapeutic reaction of the new tuberculin signify beyond question that tuberculosis was an etiological factor.

(2) The history of repeated attacks of indigestion before and during the attack, the presence of excess of indican in the urine at the very onset of his hemorrhages, and the acute desquamative involvement of the kidneys in the early part of his present trouble, make it equally certain that auto-intoxication was a factor in the etiology.

(3) Worry and anxiety over his studies at college may have played a minor rôle as a cause.

(4) Syphilis may be excluded.

(5) Human serum was injected to prevent the recurrence of the

retinal hemorrhages but had little or no influence in checking them. Possibly not enough was used, so the test cannot be regarded as final.

(6) Neither absolute rest in bed, nor moderate exercise appeared to bear any relation to the frequency of recurrence of hemorrhages into the retina in this case.

(7) Peri-vasculitis was a most pronounced feature of this case together with the retinitis proliferans, showing a diseased condition of the retinal vessels, more marked in the veins.

(8) The hemorrhages seemed to come from the retinal veins and arteries and not from the choroidal veins.

(9) The patient's blood-pressure and blood-tests were normal throughout.

(10) All treatemnt seemed of little avail in checking the hemorrhages, though he is inclined to give the tuberculin injections, the open-air treatment, and the general hygienic management of the case the chief credit in securing so good a result thus far obtained.

In looking into the literature of the subject he was struck first, by the rarity of such cases; second, by the uncertainty as to the cause of the trouble; and, thirdly, by the variety of remedies and procedures recommended for the cure of the disease—a sure sign that there is no effective remedy.

The reviewer had a case under his care for the past five years which agreed in almost all essentials with this one recorded by Davis.

Davis gives the following summary of the etiology suggested by the authorities whose names are appended. Tuberculosis (Axenfield); auto-intoxication; syphilis; inequalities of the blood-pressure, either too high or too low (Hutchinson, Krauss); decreased coagulability of the blood; increased coagulability of the blood (Collins and Mayou); malignant endocarditis (Grimsdale); hemophilia (Noll); sub-oxidation (Ziegler); naso-pharynx and accessory sinus disease (de Schweinitz); constipation (Eales); malarial fever (Kries); vicarious menstruation in females; establishment of the sexual function in the male.

As to the various remedies and procedures mentioned for the cure and prevention of this disease he appends a partial list: nitro-glycerin; ergot; calcium lactate; adrenalin chloride; gallic acid and numerous other hemostatics; iodine in its various forms; mercury in its various forms; dionin; thyroid extract (Ziegler); thyroidin; fibro-lysin; sajodin; substituting isotonic saline solution 0.85 per cent. for the diseased vitreous, about 5 c.c. Elschnig has reported one case of vitreous hemorrhage treated in this way where all other treatment had failed to give relief, and the result was highly gratifying, improving vision from just perceiving movements of the hand to .8 normal!

Galvanic electricity, the negative pole over the lids and positive pole to the nape of the neck, has been highly recommended (Black, Coleman).

Ligature of the common carotid artery has been recommended and succeeded in stopping hemorrhage into the vitreous (Mayweg).

The complications in this condition are retinitis proliferans; secondary gluacoma; softening of the eye-ball with atrophic changes.

So little can be done for these cases that we must be profoundly thankful that the disease is very rare.

Retina, Arteriosclerosis of the. See **Retina, Angiosclerosis of the.**

Retina, Asthenopia of the. See **Retinal asthenopia.**

Retina, Carcinoma of the. This is one of the very rare intraocular neoplasms. The best account of it is that furnished by U. Arisawa (*Klin. Monatsbl. f. Augenheilk.*, 52, I, p. 386, 1914) especially in the review by Geo. Coats (*Oph. Review*, p. 242, Aug., 1914). Arisawa's case occurred in a man aged 30, who suffered from a large tumor of the abdomen, probably a carcinoma of the pancreas. Four months after he first came under observation he complained of defective vision in the right eye, and a large mass projecting into the vitreous was observed. Subsequently the eye became prominent and painful and was excised. The patient died not long afterwards, but no post-mortem examination was made.

Microscopically the tumor filled about two-thirds of the vitreous, and consisted of a main mass with two smaller prominent nodules. Histologically it was a typical epithelial carcinoma, showing a tubular and alveolar strcture. The tubules were lined with a single or stratified layer of cubical and cylindrical cells; the stroma was loose and contained vessels in moderate abundance. Cystic spaces were present in places, and small papillary prominences projected into some of the lumina. There was a certain amount of necrosis and imperfect nuclear staining. The tumor merged posteriorly into the remains of the much disorganized retina, and invaded the nerve for some distance. The choroid was quite free. The cornea showed inflammatory infiltration, and there were signs of early panophthalmitis.

At first sight it seems manifest that this is a case of metastasis from the abdominal carcinoma. Yet metastatic carcinoma entirely confined to the retina is a condition which has never been described;

on the contrary, it is almost characteristic of intraocular metastasis to spare the retina, and such cases of its involvement as have been reported have always been by invasion from the choroid. Moreover, the histology of the present tumor differs from that of nearly all recorded cases of intraocular metastasis. According to Aschoff, who was consulted on the point, it presented resemblances to certain tumors of the suprarenal, and to some growths of the choroid plexuses of the cerebral ventricles.

Is it possible then that the ocular tumor may have been primary and the abdominal secondary. Arisawa gives no certain reply, although the opinion of Aschoff was rather in favor of this supposition. He analyses what is known concerning primary epithelial intraocular tumors—the simple hyperplasias of the ciliary epithelium, the more malignant infiltrating tumors for which Fuchs has suggested the name "Diktyoma," the apparently carcinomatous growths derived from the epithelium of the ciliary body, tumors originating in the pigment epithelium of the iris, and a peculiar case described by Fuchs in which proliferations of the epithelium such as are not uncommon in inflammatory membranes seemed to have taken on an unlimited infiltrating growth. From all these, however, the present case differed considerably, and from the last, which has the most tubular structure, it was distinguished by its situation not in the epithelium, but in the retina itself, by its orign in a previously normal eye, whereas in the case of Fuchs there had been severe inflammation; and by the presence of a tumor elsewhere in the body.

On the whole Arisawa appears to incline to the "primary" as opposed to the "metastatic" origin of the tumor. One type of primary malignant tumor of the retina proper is already known—glioma; to postulate another would require stronger evidence than can be derived from a case in which a large abdominal tumor, not histologically examined, was present, in which, moreover, according to the case-history, the abdominal tumor was present before there were any ocular symptoms. The author erroneously states that only one case of metastatic sarcoma of the retina has been described; in addition to the case of Heine quoted by him, an instance has been reported by Ballantyne (*Trans. Ophth. Soc.*, XXVI, 1906, p. 111), in whose paper also further references will be found.

Retina, Coarctate. A funnel-shaped detachment of the retina caused by a fluid exudation between the retina and the choroid.

Retina, Coloboma of the. See pp. 2344, and 2895, Vol. IV of this *Encyclopedia.*

Retina, Concussion of the. COMMOTIO RETINÆ. BERLIN'S EDEMA. TRAUMATIC RETINITIS. See p. 2517, Vol. IV of this *Encyclopedia.*

Retina, Cones of the. See **Retinal cones.**

Retina, Congenital anomalies of. See p. 2895, Vol. IV of this *Encyclopedia.*

Retina, Cyanosis of the. See p. 3607, Vol. V of this *Encyclopedia.*

The *Ophthalmic Year-Book* for 1916 (p. 204) notes two additional cases.

Weidler's patient, a girl of 9 years, was a "blue baby" at birth; had purple lips, tongue, mucous membranes and nails; hands and feet cold. Was unable to play or endure a slight amount of exertion without undue fatigue and exhaustion. Veins and arteries of the eye-ground were tremendously enlarged and tortuous. The retina gave a bluish-red reflex. Lamb's patient, a girl of 13 years, had the conjunctiva congested and purplish. Arteries and veins of the retina were tortuous and dilated with no pulsation. Normal vision. Color of retinal arteries differed from the veins. No connection, therefore, as pointed out by Nagel, existed between the two sides of the heart. The probable diagnosis in the case was pulmonary stenosis and patent ductus arteriosus.

Retina, Cyst of the. This is a very rare tumor. F. Deutschmann (*Beiträge zur Augenheilk.,* April, 1914) records a case in which the presence of a large globular retinal detachment in the left eye led several experienced oculists to diagnose intraocular tumor, in consequence of which the eye was enucleated. When the eyeball was dissected, no trace of tumor could be found, nor could anything be seen with the naked eye to explain the ophthalmoscopic picture. This was made clear only by the subsequent behavior of the right eye, which very soon presented a similar tumor-like mass. This disappeared completely, and periodical examinations detected the appearance and disappearance of retinal cysts of varying size and number, chiefly situated in the region of the ciliary body. Retinal cysts were last seen in October, 1913, and more recently the fundus presented for a time a macular hemorrhage with central scotoma, and some delicate yellowish spots and lines, with a few pigment spots. General investigation of the patient found signs of a pronounced emphysema and polycythemia. Microscopic examination of the enucleated eye resulted in the discovery of a cystic degeneration of the periphery of the retina. The cysts were situated in the internuclear layer.

The author attributes the formation of the cysts to an abnormal permeability of the retinal vessels related to the emphysema and the accompanying venous stasis and cardiac embarrassment. The possibility of an angioneurotic basis is also suggested.

Velhagen (*Klin. Monatsbl. f. Augenheilk.*, Dec., 1912) also reports a case which was visible with the ophthalmoscope. A second case showed cysts which were not visible ophthalmoscopically. Both eyes had become glaucomatous before enucleation. Since glaucoma impedes resorption, the author considers this of importance in the etiology.

In Derby's (*Oph. Year-Book,* p. 369, 1912) case of bilateral retinal detachment the right eye showed a rounded swelling at the temporal side of the disc, which it overhung. It protruded 6 D. into the vitreous, and was distinct from the surrounding retinal detachment. A similar swelling was seen in the outer part of the fundus. The two examples of retinal cyst studied by Cavara were also associated with retinal separation, but were only discovered after enucleation. They occurred in the external granular layer of the detached retina, and this layer formed their outer and a part of their inner wall.

Natanson (Graefe's *Archiv f. Ophthal.*, 67, 2, 1907) gives an account of two cases of microphthalmos with cyst formation. His paper is reviewed by Henderson in the *Oph. Review,* May, 1907.

In the first case the development of the eye was very rudimentary, only the pigment membrane part of the primitive ectodermal layer being present. The lens was partly formed in the tissue of the uninvaginated distal layer. Two cysts were present, in the smaller of which the optic nerve ended. The retina was present in the cysts with the outer layers facing the cavity, "retina perversa." The intra-cranial parts of the optic nerve, chiasma, tracts and lateral geniculate bodies were atrophic.

In the second case the eyes were much more developed. The lens lay in the vitreous, but was only partly formed. Two cysts were present, the smaller of which was solid, and in this the optic nerve ended. In both cysts "retina perversa" was present. A large cleft, in the position of the primitive cleft, was present in the eye, and communicated with both cysts. In the neighborhood of the cleft there was on the left side some inflammatory change.

The author collected 74 more recorded cases, and is of the opinion that all the cases fall into two groups.

Group 1 includes those cases in which a microphthalmic eye is present, fairly well developed, with a cleft through which the retina passes to line the cyst or cysts. There is never any communication between the cavity of the vitreous and that of the cyst. The optic nerve is feebly developed, and may terminate in the bulb above the cyst neck or in the cyst neck itself.

Group 2 includes those cases in which the eye is either absent or in a very rudimentary state of development. If present it contains neither lens, vitreous nor retina, and remains in communication with the back part of the cyst.

In regard to the pathogenesis of group 2, the author agrees with Mitvalsky in believing the cause to lie in arrested development of the primary optic vesicle. The distal layer undergoes no invagination, but proceeds to differentiate, thus forming the perverse arrangement of the retina. The proximal layer develops into pigment epithelium, and is surrounded by the more or less developed mesodermal structures.

While admitting that Mitvalsky's hypothesis of a partial invagination may explain some of the cases in group 1, Natanson believes that these cases originate in the stage of the secondary optic vesicle, and are connected with the incomplete closure of the fetal optic cleft. That they have any connection with the ectasis of a coloboma is negatived by the perverse arrangement of the retina, and by the fact that the cyst communicates not with the vitreous cavity but with the space between the pigment membrane and retina.